Staging Opportunities for Project X

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on behalf of the PX Team

Accelerator Physics and Technology Seminar
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Outline

- Project Goals/Reference Design
- Staging Scenarios
- R&D Program
- Status and Strategy

Our websites:

http://projectx.fnal.gov

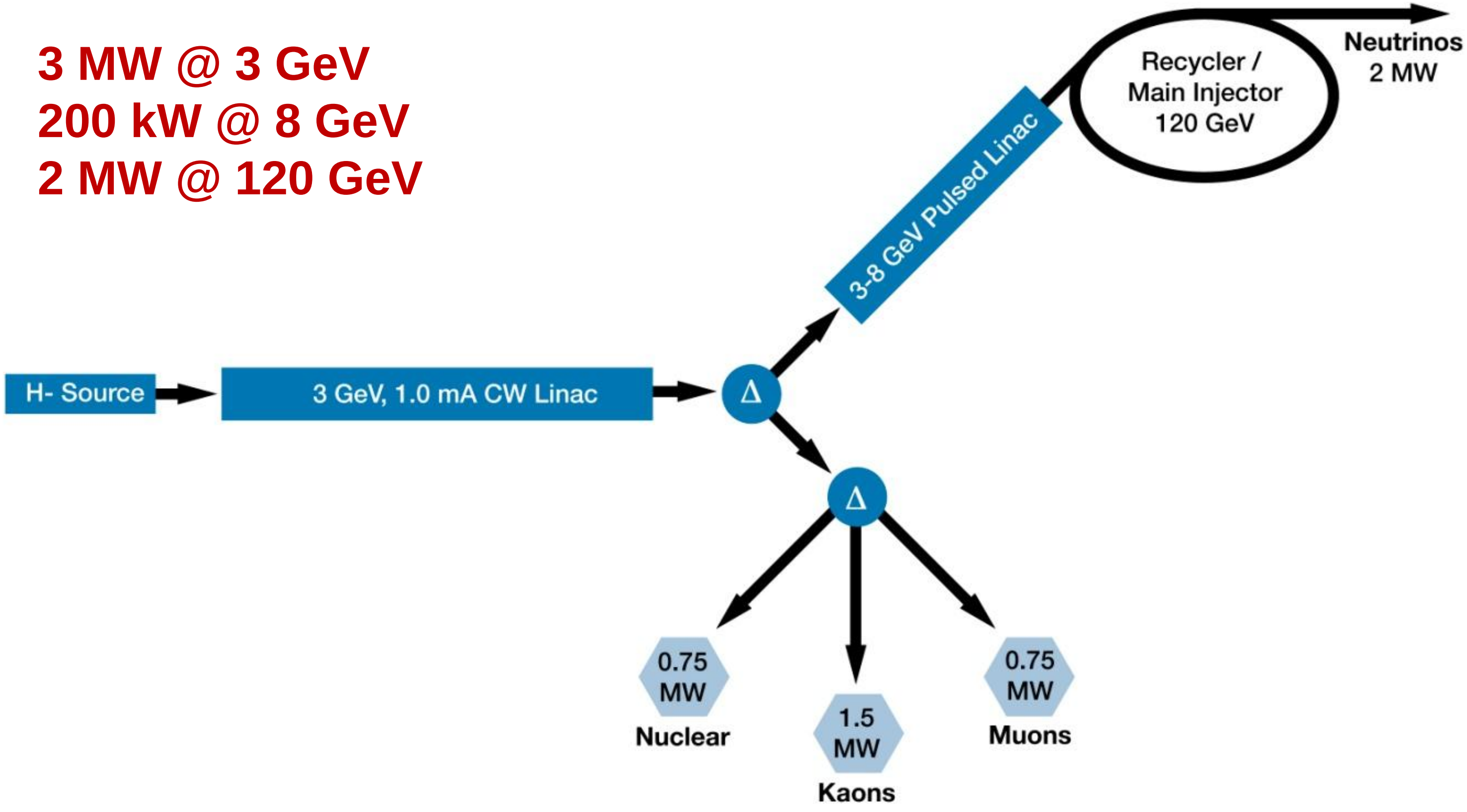
http://projectx-docdb.fnal.gov

Project Goals
Mission Elements

- A neutrino beam for long baseline neutrino oscillation experiments
  - 2 MW proton source at 60-120 GeV
- MW-class low energy proton beams for kaon, muon, neutrino, and nuclei based precision experiments
  - Operations simultaneous with the neutrino program
- A path toward a muon source for possible future Neutrino Factory and/or a Muon Collider
  - Requires ~4 MW at ~5-15 GeV
- Possible missions beyond particle physics
  - Energy applications

Reference Design

3 MW @ 3 GeV
200 kW @ 8 GeV
2 MW @ 120 GeV



Reference Design Capabilities

- 3 GeV CW superconducting H- linac with 1 mA average beam current.
  - Flexible provision for variable beam structures to multiple users
    - CW at time scales >1 μsec, 20% DF at <1 μsec
  - Supports rare processes programs at 3 GeV
  - Provision for 1 GeV extraction for nuclear energy program
- 3-8 GeV pulsed linac capable of delivering 300 kW at 8 GeV
  - Supports the neutrino program
  - Establishes a path toward a muon based facility
- Upgrades to the Recycler and Main Injector to provide ≥ 2 MW to the neutrino production target at 60-120 GeV.

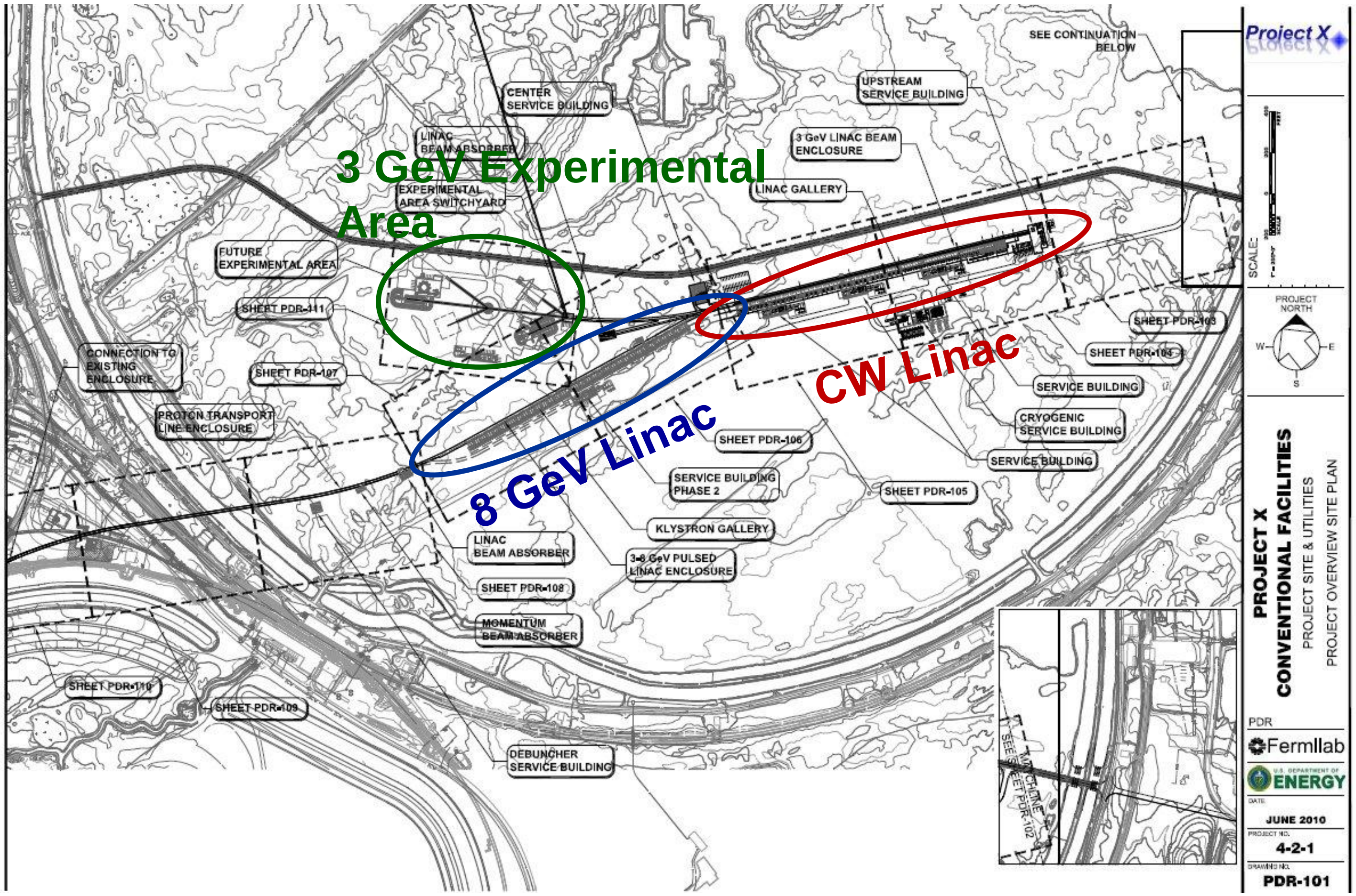
⇒ ***Utilization of a CW linac creates a facility that is unique in the world, with performance that cannot be matched in a synchrotron-based facility.***

Reference Design Performance Goals

Linac		
Particle Type	H^-	
Beam Kinetic Energy	3.0	GeV
Average Beam Current	1	mA
Linac pulse rate	CW	
Beam Power	3000	kW
Beam Power to 3 GeV program	2870	kW
Pulsed Linac		
Particle Type	H^-	
Beam Kinetic Energy	8.0	GeV
Pulse rate	10	Hz
Pulse Width	4.3	msec
Cycles to MI	6	
Particles per cycle to MI	2.6×10^{13}	
Beam Power	340	kW
Beam Power to 8 GeV program	200	kW
Main Injector/Recycler		
Beam Kinetic Energy (maximum)	120	GeV
Cycle time	1.4	sec
Particles per cycle	1.6×10^{14}	
Beam Power at 120 GeV	2200	kW

simultaneous

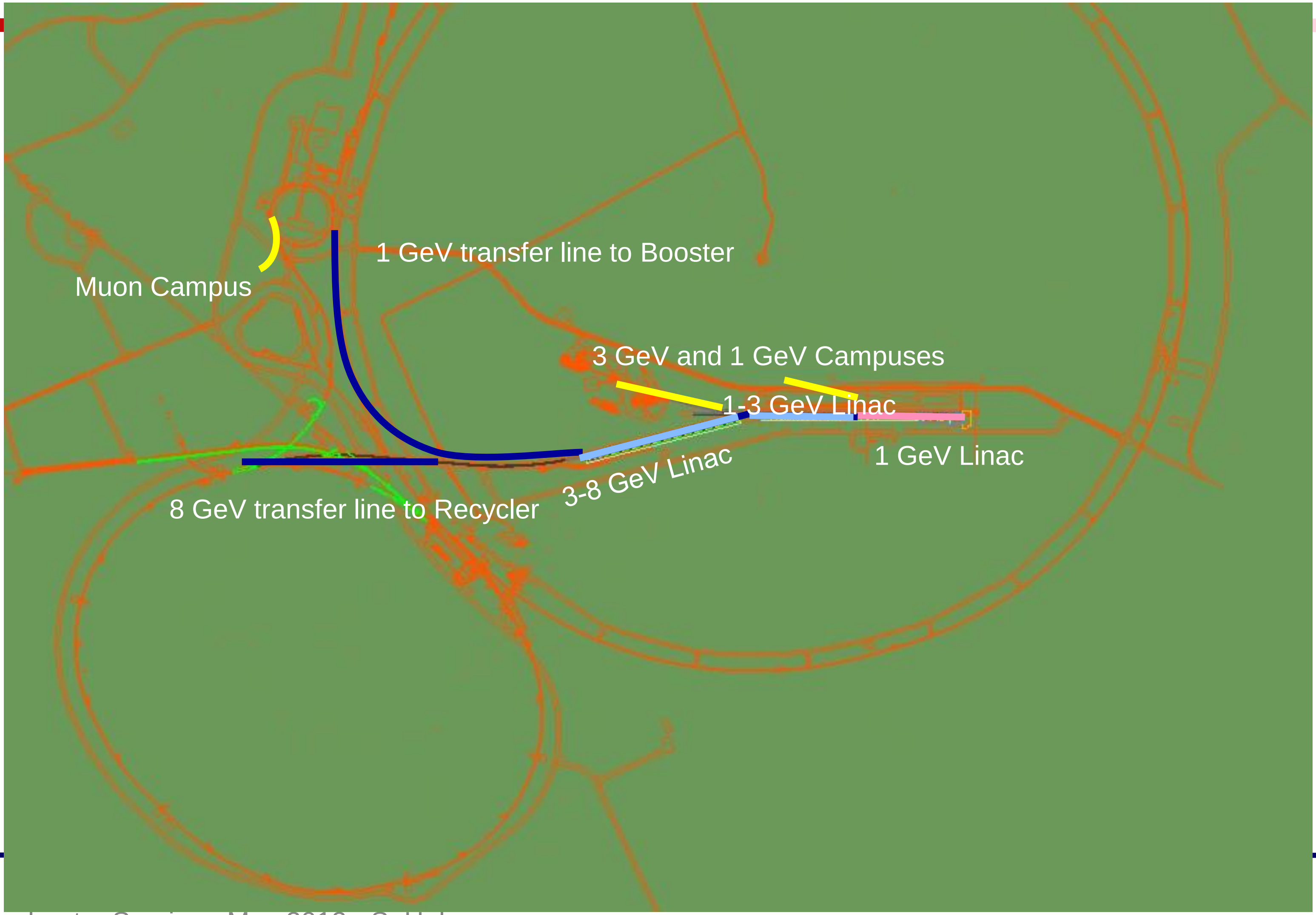
Reference Design Siting



Staging Opportunities

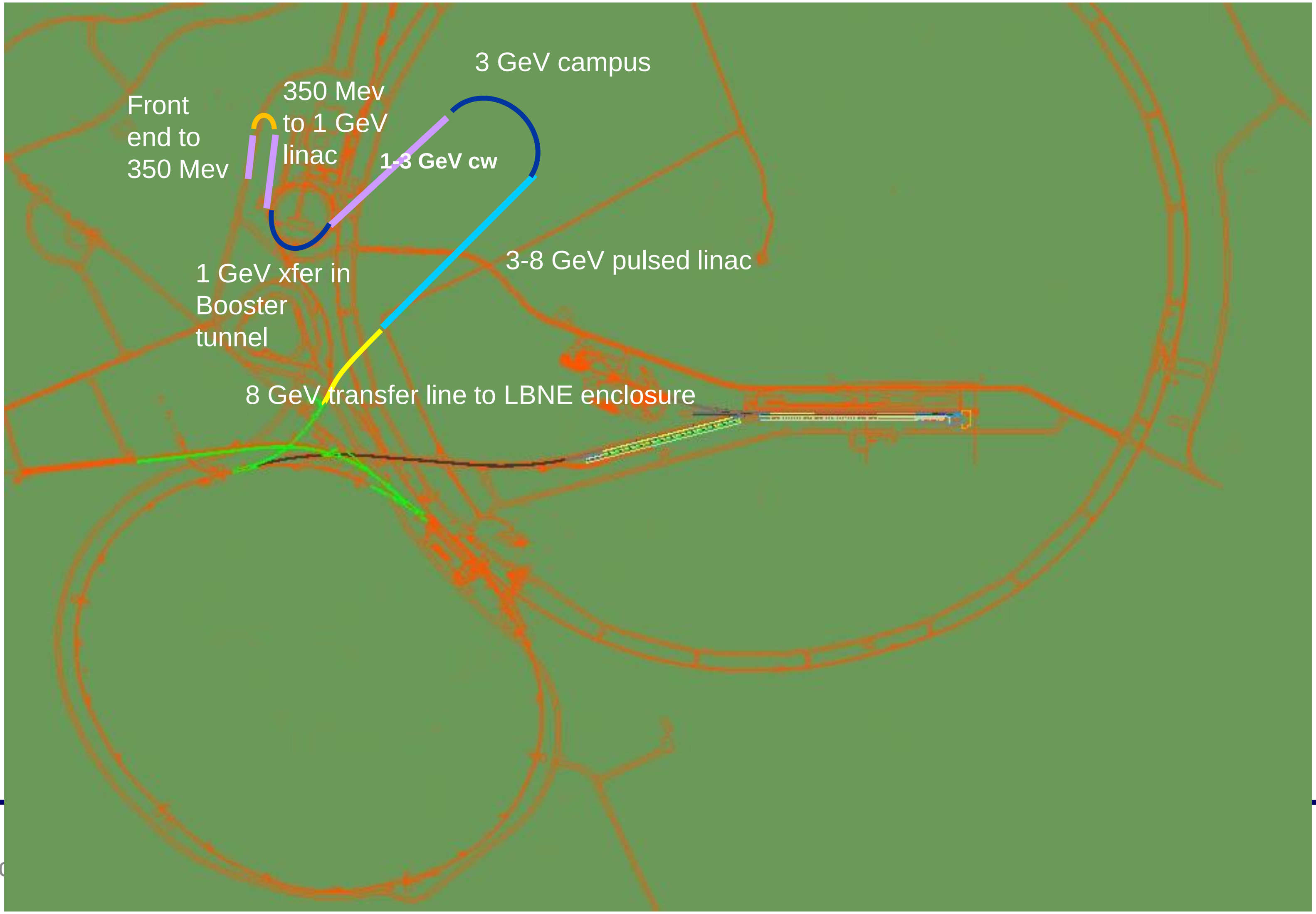
- Briefing to DOE/OHEP on January 27, 2012
- Staging principles
  - Significant physics opportunities at each stage
  - Cost of each stage substantially <$1B
  - Achieve full Reference Design capabilities (including upgradability) at end of final stage
  - Fit within a funding profile devoting <20% of OHEP budget to construction projects in any year
- We presented a four stage plan, consistent with these principles.
- We subsequently provided DOE with cost profiles for the first three stages, including possible international in-kind contributions.

Staging



Muon Campus
1 GeV transfer line to Booster
3 GeV and 1 GeV Campuses
1-3 GeV Linac
1 GeV Linac
3-8 GeV Linac
8 GeV transfer line to Recycler

Staging Alternative



Staging Options
Stage 1

- Note: Proton Improvement Plan (PIP) is scoped to support Proton Source operations through 2025
- Scope
  - 1 GeV CW linac injecting into upgraded Booster
- Performance
  - 1 MW at 1 GeV
  - ~1.2 MW at 120 GeV, up to 0.8 MW at 60 GeV (if utilize all Booster cycles)
- Utilization of the existing complex
  - Booster, Main Injector and Recycler (with PIP)
  - NuMI (upgraded) or LBNE target system
  - Muon Campus
  - 400 MeV Linac retired – eliminates major reliability risk
- Physics Program
  - Long and short baseline neutrinos
  - Rare kaons from MI (slow-spill)
  - Muon campaign
  - Ultra-cold neutrons and edms
  - Materials and energy applications test facility

Stage 1 Performance Goals (Proton Source)

		NOvA/LBNE		PX Stage 1		
MI/Recycler						
	Beam Energy	**120**	**60**	**120**	**60**	**GeV**
	Cycle Time	1.33	0.80	1.20	0.80	sec
	Protons per pulse	4.9E+13	4.9E+13	7.5E+13	7.5E+13	ppp
	Slip Stacking Efficiency	95	95	95	95	%
	Beam Power	**0.70**	**0.58**	**1.20**	**0.90**	**MW**
	Normalized Beam Emittance (95%)	20	20	20	20	π mm-mr
	Laslett Tune Shift (injection)	-0.06	-0.06	-0.09	-0.09	
Booster						
	Injection Energy (Kinetic)	0.4	0.4	1.0	1.0	GeV
	Injection Momentum	1.0	1.0	1.7	1.7	GeV/c
	Extraction Energy (Kinetic)	8.0	8.0	8.0	8.0	GeV
	Revolution Period (Injection)	2.2	2.2	1.8	1.8	μsec
	Cycles to Recycler	12	12	12	12	
	Booster Cycle Rate	15	15	15	15	Hz
	Beam Cycle Rate	**9**	**15**	**10**	**15**	**Hz**
	Protons per Pulse	**4.3E+12**	**4.3E+12**	**6.6E+12**	**6.6E+12**	
	Injection Time	0.02	0.02	1.05	1.05	ms
	Injected Turns	**9**	**9**	**613**	**613**	
	Average Delivered Beam Power	49	82	84	126	kW
	Normalized Beam Emittance (95%)	20	20	20	20	π mm-mr
	Laslett Tune Shift (injection)	**-0.35**	**-0.35**	**-0.21**	**-0.21**	
Linac						
	Beam Energy (Kinetic)	**0.40**	**0.40**	**1.00**	**1.00**	**GeV**
	Beam Momentum	0.95	0.95	1.70	1.70	GeV/c
	Beam Current	35.0	35.0	1.0	1.0	mA
	Linac Beam Duty Factor	**1.8E-04**	**2.9E-04**	**1.1E-02**	**1.6E-02**	
	Beam Power to Booster	2	4	11	16	kW
	Full Momentum Deviation over Injection Time	0.0	0.0	8.3	8.3	MeV/c

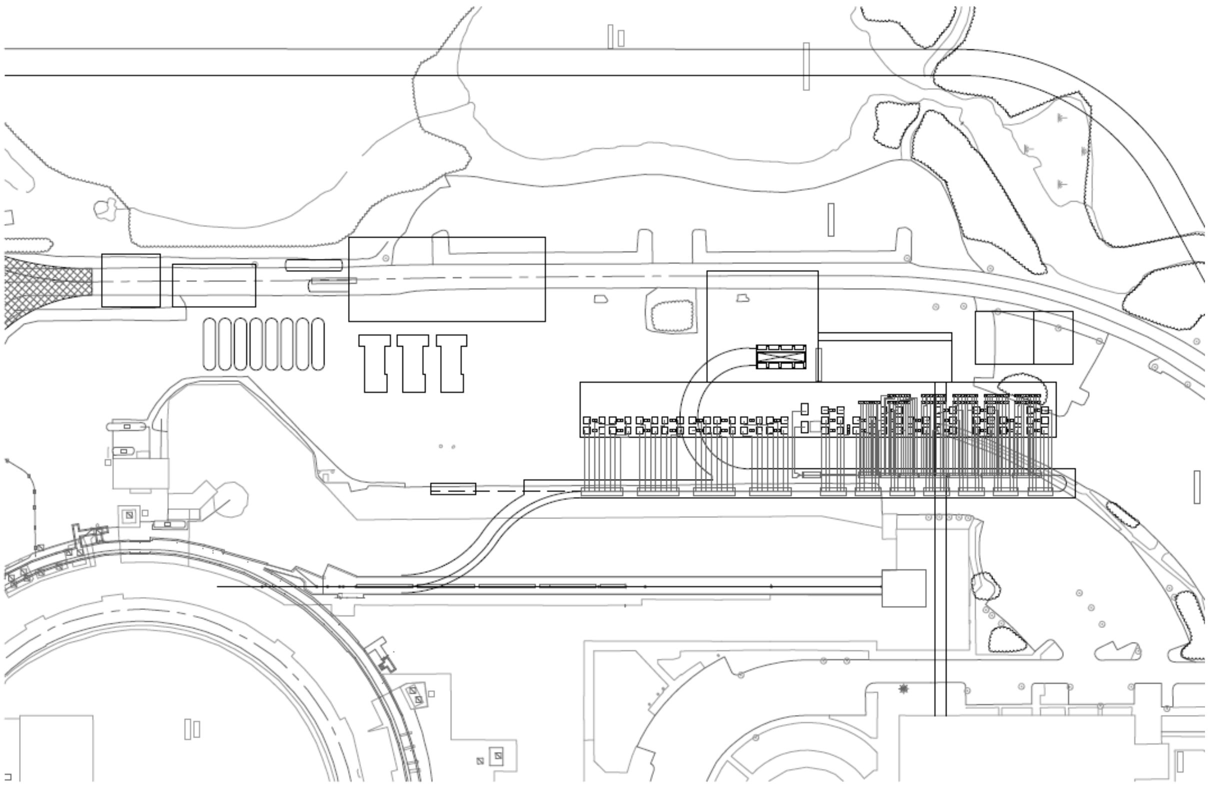
Stage 1
Performance Considerations

- Linac
  - Beam current
  - Duty factor?
- Booster
  - H- injection @ 1 GeV, 500-600 turns
  - Beam acceleration/transition
  - Longitudinal emittance
  - Note: Booster has operated above 6E12 in studies (longitudinal emittance?)
- Recycler
  - Slip stacking: require $\Delta p(95\%) = \pm 8$ MeV/c from Booster
- Main Injector
  - Acceleration/transition
- NuMI target
  - >1 MW operations?

$\Rightarrow$***Task Force established to develop a conceptual plan***

Project X

Stage 1
Alternative ("PLL") Location



Staging Options
Stage 2

- Scope
  - 1-3 GeV CW linac
  - 3 GeV experimental facilities + 2 experiments
- Performance
  - 3 MW at 3 GeV
  - ~1.2 MW at 120 GeV, 0.8 MW at 60 GeV (if utilize all Booster cycles)
- Utilization of the existing complex
  - Booster, Main Injector and Recycler (with PIP)
  - NuMI (upgraded) or LBNE target system
- Physics Program
  - Long and short baseline neutrinos
  - MW-class kaon and muon physics programs
  - Ultra-cold neutrons and edms
  - Materials and energy applications test facility

Staging Options
Stage 3

- Scope
  - 3-8 GeV pulsed linac
  - Main Injector Recycler upgrades
  - Short baseline neutrino facility/experiment
- Performance
  - 3 MW at 3 GeV
  - 50-200 kW at 8 GeV
  - >2 MW at 60-120 GeV
- Utilization of the existing complex
  - Main Injector and Recycler
  - LBNE beamline/target
  - 8 GeV Booster retired – eliminates major reliability risk
- Physics Program
  - Multi-MW long and short baseline neutrinos
  - MW-class kaon and muon physics programs
  - Ultra cold neutrons and edms
  - Materials and energy applications test facility

Staging Options
Stage 4

- Scope – beyond the Reference Design
  - Current upgrade of CW and pulsed linac
  - Main Injector & Recycler upgrades
  - Step toward a NF or MC
- Performance
  - 3 MW at 3 GeV
  - 4 MW at 8 GeV
  - >2 MW at 60-120 GeV
- Utilization of the existing complex
  - Main Injector and Recycler
  - LBNE beamline/target
- Physics Program
  - Long baseline with ultra-high power low & high energy neutrino sources
  - Ultra-high power short baseline neutrinos
  - MW-class kaon and muon physics programs
  - Materials and energy applications test facility

Project X Staged Physics Program

Program:	NOνA + Proton Improvement Plan	Stage-1: 1 GeV CW Linac driving Booster & Muon, EDM programs (MI>80 GeV)	Stage-2: Upgrade to 3 GeV CW Linac (MI>80 GeV)	Stage-3: Project X RDR (MI>60GeV)	Stage-4: Beyond RDR: 8 GeV power upgrade to 4MW
MI neutrinos	470-700 kW**	515-1200 kW**	1200 kW	2300 kW	2300-4000 kW
8 GeV Neutrinos	15 kW + 0-50 kW**	0-40 kW* + 0-90 kW**	0-40 kW*	85 kW	3000 kW
8 GeV Muon program e.g, (g-2), Mu2e-1	20 kW	0-20 kW*	0-20 kW*	85 kW	1000 kW
1-3 GeV Muon program	-----	80 kW	1000 kW	1000 kW	1000 kW
Kaon Program	0-30 kW** (<30% df from MI)	0-75 kW** (<45% df from MI)	1100 kW	1100 kW	1100 kW
Nuclear edm ISOL program	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
Ultra-cold neutron program	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
Nuclear technology applications	none	0-900 kW	0-900 kW	0-900 kW	0-900 kW
# Programs:	4	8	8	8	8
Total* power:	585-735 kW	1660-2240 kW	4230 kW	5490 kW	11300kW

* Operating point in range depends on MI energy for neutrinos.

** Operating point in range is depends on MI injector slow-spill duty factor (df) for kaon program.

R&D Program

- Goal is to mitigate risk: technical, cost, and schedule
- Primary elements of the R&D program:
  - Primary technical risk element is the front end
    - CW ion source/RFQ
    - Wideband chopping with high (1×10^{-4}) extinction rate
    - (Low-β) acceleration through superconducting resonators with minimal halo formation
    - MEBT beam absorber (>8 kW)
  - Development of an H- injection system
  - Superconducting rf development
    - Cavities, cryomodules, rf sources – CW to long-pulse
  - High Power targetry
  - Upgrade paths: Multi-MW low energy neutrinos and Muon Collider
  - *All of these elements are required at Stage 1, with the exception of 1.3 GHz pulsed RF*
  - First and third elements addressed in an integrated system test: PXIE
- Goal is to complete R&D phase by the end of 2016

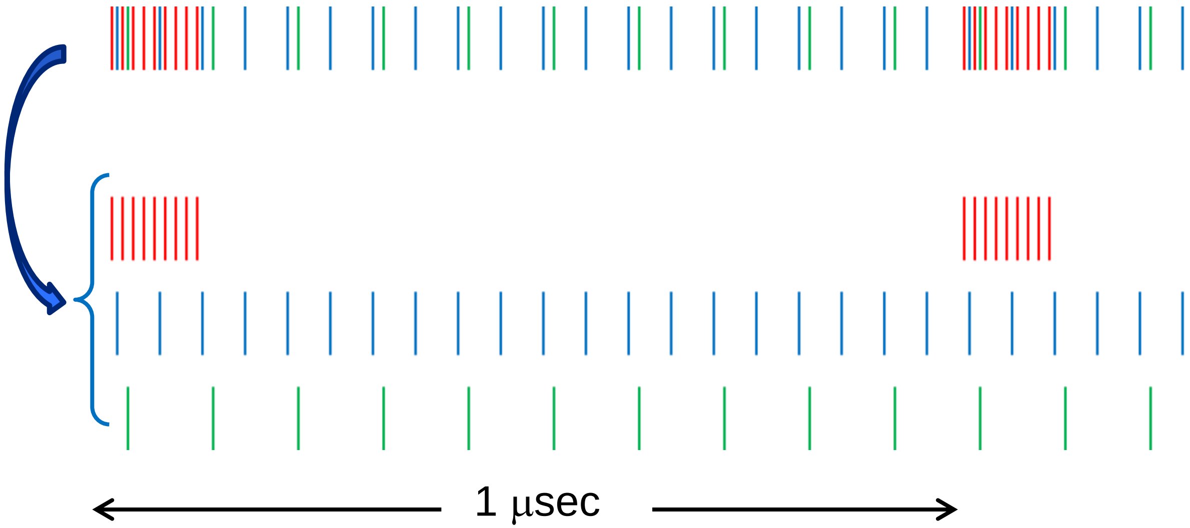
Operating Scenario
3 GeV Program

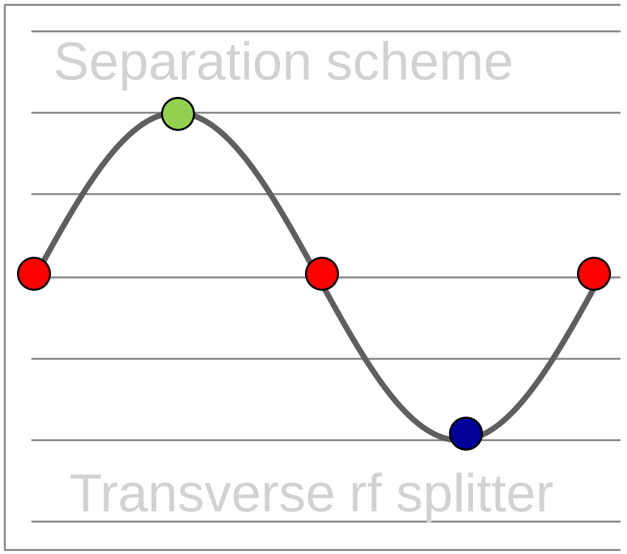
<u>1 μsec period at 3 GeV</u>

Muon pulses (12e7) 162.5 MHz, 80 nsec	700 kW
Kaon pulses (12e7) 27 MHz	1540 kW
Nuclear pulses (12e7) 13.5 MHz	770 kW

Ion source and RFQ operate at 4.4 mA

77% of bunches are chopped @ 2.1 MeV ⇒ maintain 1 mA over 1 μsec

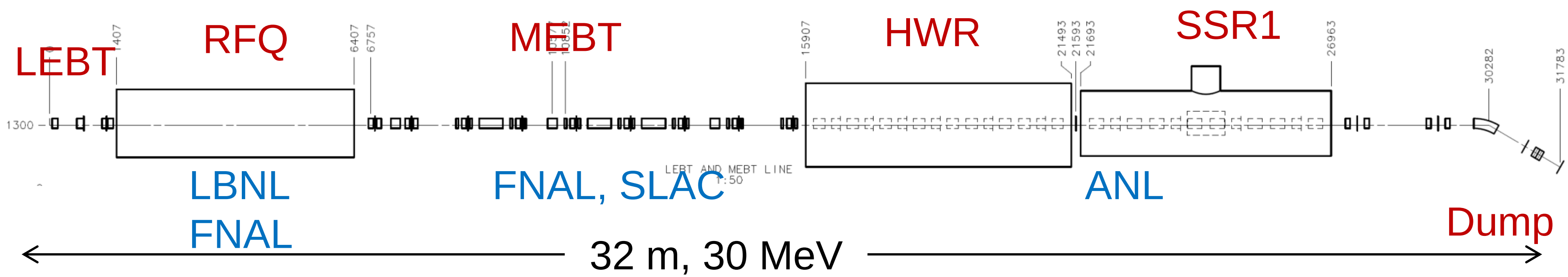




Project X Injector Experiment PXIE

- PXIE is the centerpiece of the Project X R&D program
  - Integrated systems test for Project X front end components
    - Validate the concept for the Project X front end, thereby minimizing the primary technical risk element within the Reference Design.
    - Operate at full Project X design parameters
- Systems test goals
  - 1 mA average current with 80% chopping of beam delivered from RFQ
  - Efficient acceleration with minimal emittance dilution through ~30 MeV
  - Achieve in 2016
- PXIE should utilize components constructed to PX specifications wherever possbile
  - Opportunity to re-utilize selected pieces of PXIE in PX/Stage 1
- Collaboration between Fermilab, ANL, LBNL, SLAC, India

PXIE Program



PXIE will address the address/measure the following:

- Ion source lifetime
- LEBT pre-chopping
- Vacuum management in the LEBT/RFQ region
- Validation of chopper performance
- Kicker extinction
- Effectiveness of MEBT beam absorber
- MEBT vacuum management
- Operation of HWR in close proximity to 10 kW absorber
- Operation of SSR with beam
- Emittance preservation and beam halo formation through the front end

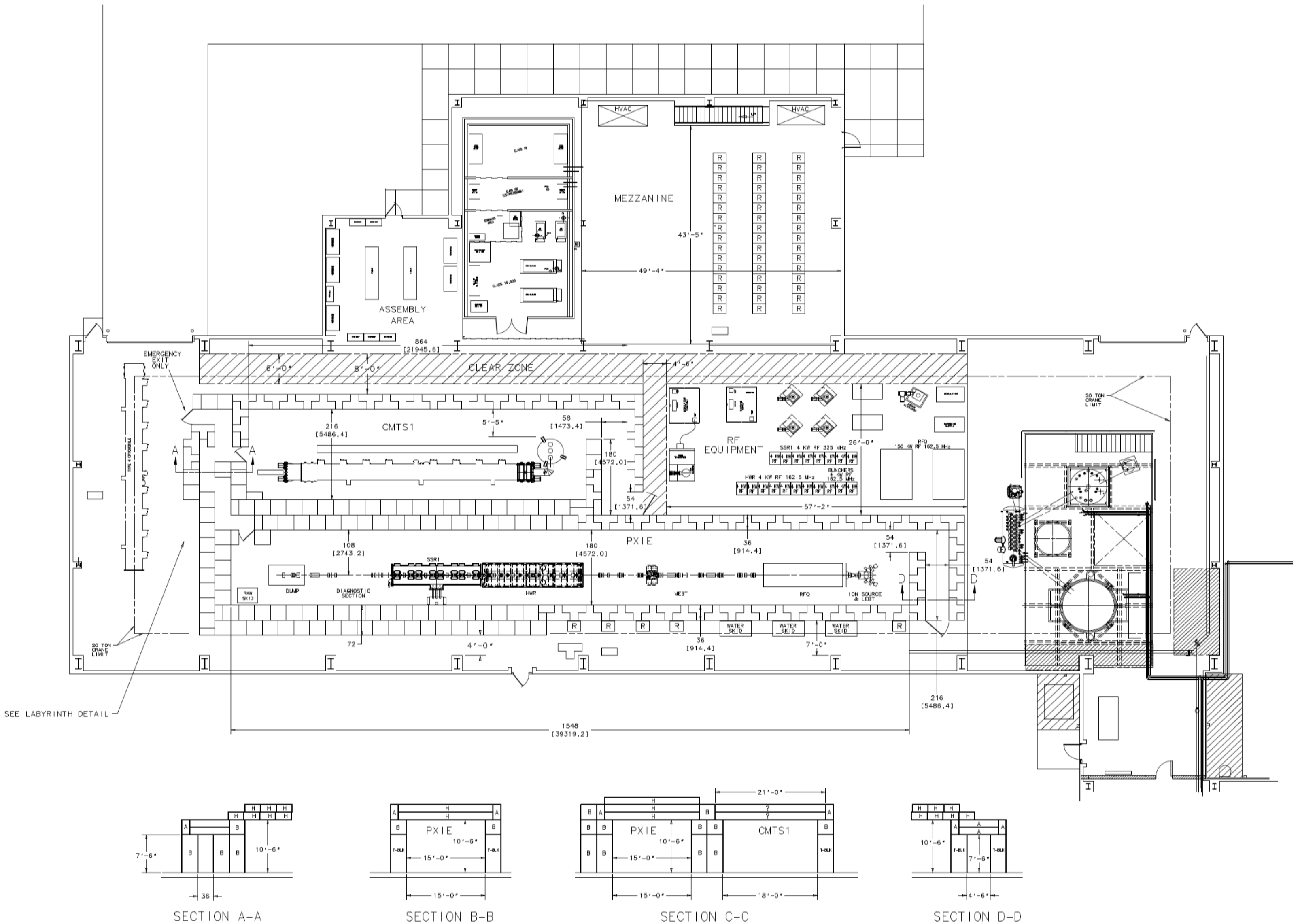
PXIE Status

- Whitepaper available describing rationale, goals, plan
  - Shared with DOE

  http://projectx-docdb.fnal.gov/cgi-bin/ShowDocument?docid=966
- Technical Review March 6-7

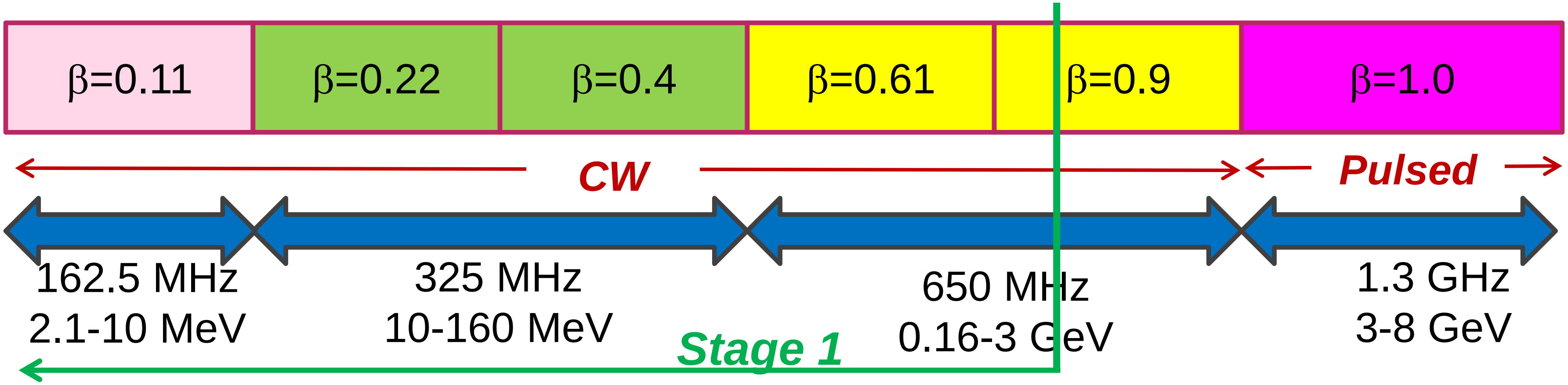
  https://indico.fnal.gov/conferenceDisplay.py?confId=5278
- Preferred location identified (CMTF)
- Cost estimate /funding plan will allow completion of the full scope of PXIE in 2016
  - Requires maintenance of Project X and SRF budgets at FY12 levels
- DOE has requested that we organize and execute PXIE as a “project”, not a “Project”
  - Organization Chart
  - Program Design Handbook
  - Resource Loaded Schedule
  - DOE oversight
    - Periodic reporting
    - Periodic review

PXIE @ CMTF



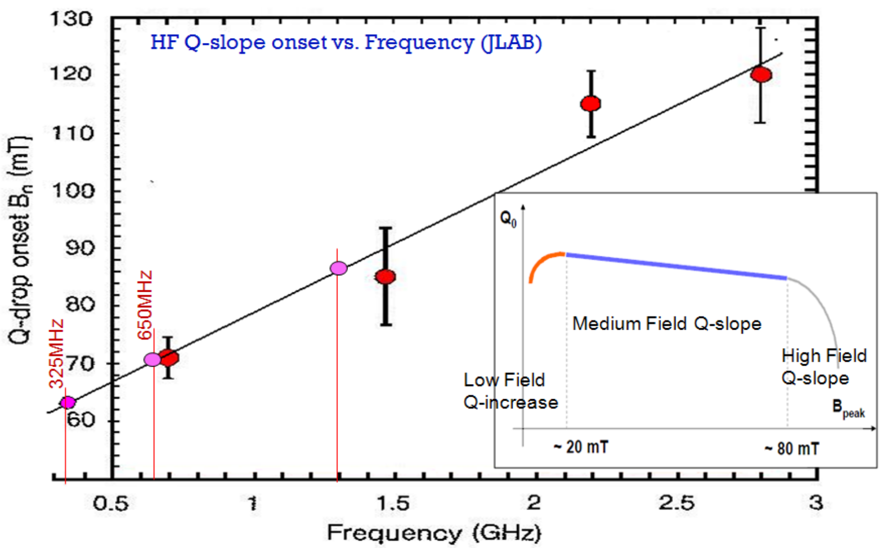
MEZZANINE
ASSEMBLY AREA
CLEAR ZONE
EMERGENCY EXIT ONLY
CMTS1
PXIE
RF EQUIPMENT
HVAC
SSR1
DUMP
DIAGNOSTIC SECTION
HWR
MEBT
RFQ
ION SOURCE & LEBT
WATER SKID
20 TON CRANE LIMIT
SEE LABYRINTH DETAIL
864 [21945.6]
1548 [39319.2]
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D

SRF R&D Technology Map

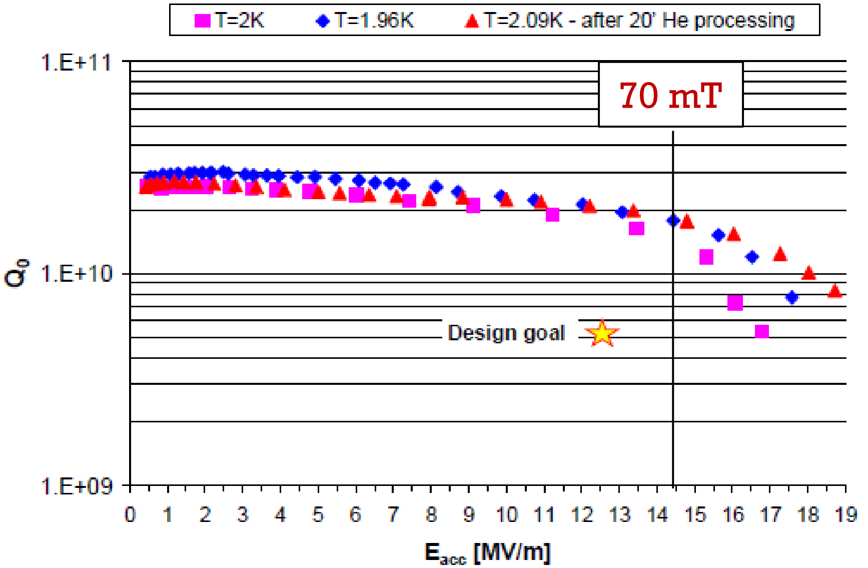


Section	Freq	Energy (MeV)	Cav/mag/CM	Type
HWR (β_G=0.1)	162.5	2.1-10	8/8/1	HWR, solenoid
SSR1 (β_G=0.22)	325	10-42	16/10/ 2	SSR, solenoid
SSR2 (β_G=0.47)	325	42-160	36/20/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-460	42 /14/7	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	460-3000	152/19/19	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	3000-8000	224 /28 /28	9-cell elliptical, quad

Project X Choice of Cavity Parameters



Example: SNS, 805 MHz, β=0.81



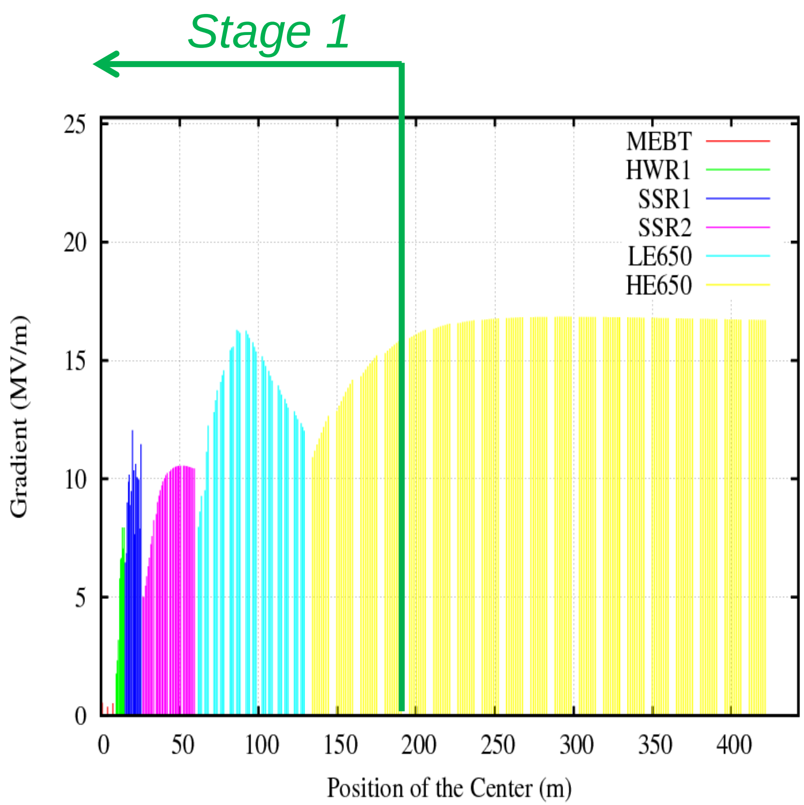
CW Linac assumptions:

162.5 MHz	$B_{pk} < 60$mT
325 MHz	$B_{pk} < 70$mT
650 MHz	$B_{pk} < 70$mT
1300 MHz	$B_{pk} < 80$mT

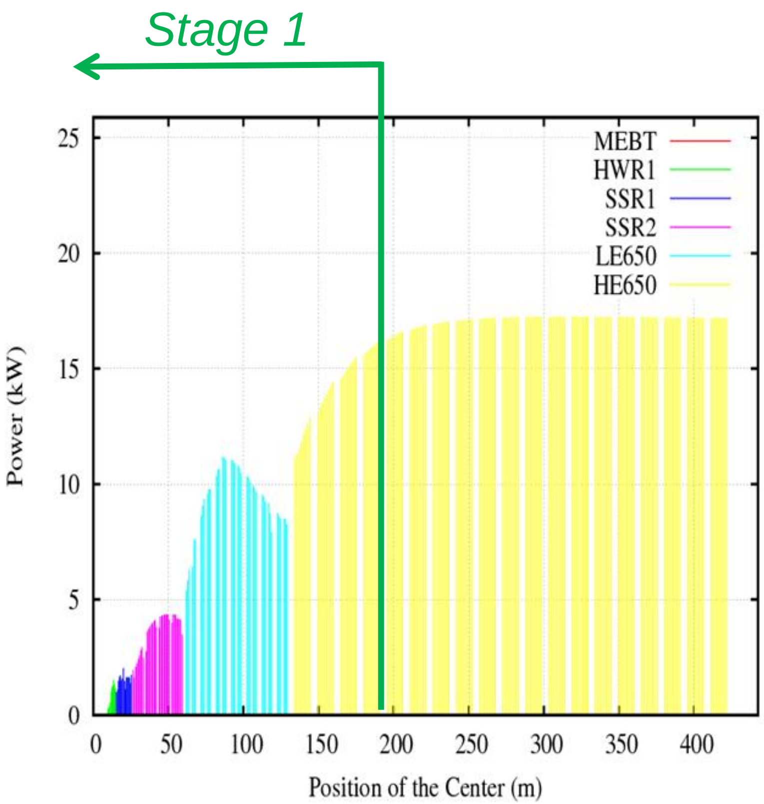
$\Rightarrow E_{acc} = 15.6$ MV/m; $Q_o \sim 1.7\cdot10^{10}$ @ 2 K

SRF Acceleration Parameters

Energy Gain



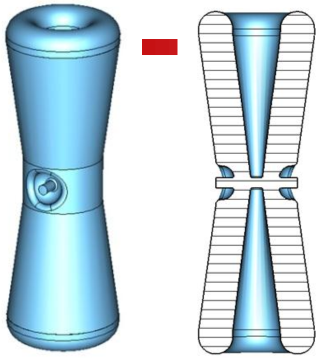
Beam Power



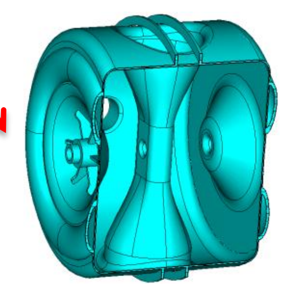
SRF Development
Cavity/ CM Status

- 1300 MHz
  - 90 nine-cell cavities ordered
  - 60 received (32 from U.S. industry:16 from AES, 16 from Niowave-Roark)
  - ~ 40 processed and tested, ~20 dressed
  - 2 CM built: one from a DESY kit and a second U.S. procured
    - CM1 testing at NML is complete; CM2 was delivered to NML April 26 for testing
- 650 MHz
  - JLab built two single-cell β =0.61 cavities
  - Six β = 0.9 single-cell cavities ordered from U.S. industry recently arrived
  - Order for six β = 0.61 (2 JLab, 2 FNAL design) single-cell cavities in industry
- 325 MHz
  - 2 SSR1 β =0.22 cavities (Roark, Zanon) both VTS tested
    - 1 of these dressed and tested at STF
  - 2 SSR1 being fabricated in India (IUAC, spring 2012)
  - 10 SSR1 ordered from Industry (Niowave-Roark)
    - 6 delivered; 1 VTS tested, second soon to follow
- Design work advanced on 325 MHz CM, but proceeding with lower priority on 650 MHz CM (not required in PXIE)

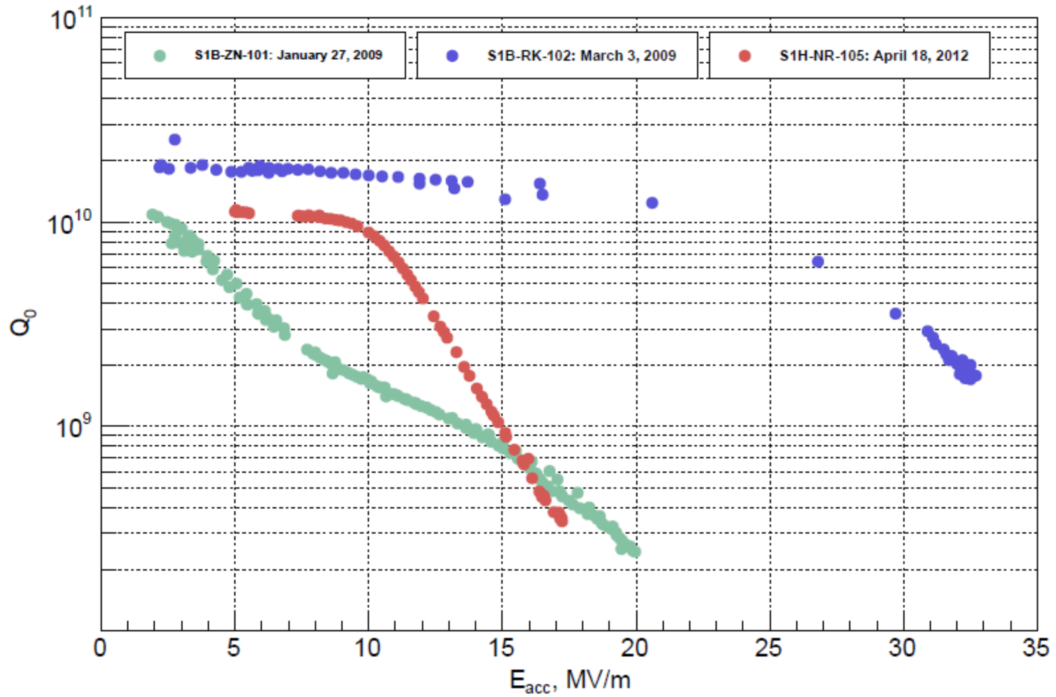
Project X 162.5 and 325 MHz Cavities



- HWR (β_G = 0.11) Half Wave Resonator
  - EM and mechanical design underway at ANL
  - Similar to cavities & CM already manufactured by ANL
- SSR1 (β_G = 0.22) Single Spoke Resonator
  - Initiated under HINS program → more advanced
  - 8 prototype cavities to date
    - 3 tested as bare cavities at 2K
    - One dressed and tested at 4.8K
- SSR2(β_G = 0.47) Single Spoke Resonator
  - EM design complete
  - Mechanical design in progress

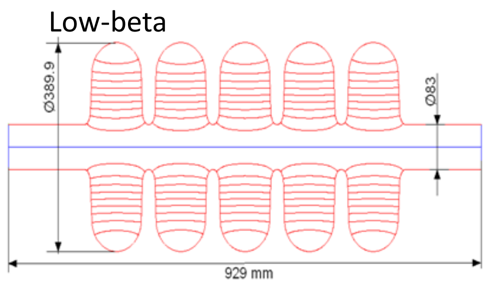


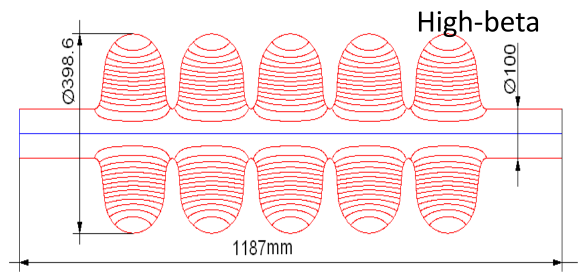
SSR1 Performance



- Three bare cavities tested; the second one met the PX specification
  - Need to understand difference between March 2009 and April 2012 cavities
- One dressed cavity tested at 4.8K
  - Modifications in process to allow dressed cavity testing at 2 K

650 MHz Cavity
E-M Design (Fermilab)





β_G	0.61	0.9	
Length (from iris to iris)	705	1038	mm
Aperture	83	100	mm
Cavity diameter	389.9	400.6	mm
R/Q, Ohm	378	638	Ω
G - factor	191	255	Ω
Max. gain per cavity (ϕ-0)	11.7	19.3	MeV
Gradient	16.6	18.6	MV/m
Max surface electric field	37.5	37.3	MV/m
E_{pk}/E_{acc}	2.26	2.0	
Max surf magnetic field	70	70	mT
B_{pk}/E_{acc}	4.21	3.75	mT/(MeV/m)

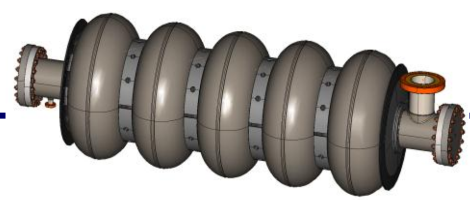
650 MHz Cavities

- For purposes of cryogenic system design, the dynamic heat load limited to 250 W at 2K per cryomodule
    - <35W per cavity (β_G = 0.61) and <25W per cavity (β_G = 0.9)
    - Q0 = 1.7E10
- Multiple single cells received from JLab and industry

β=0.9, AES

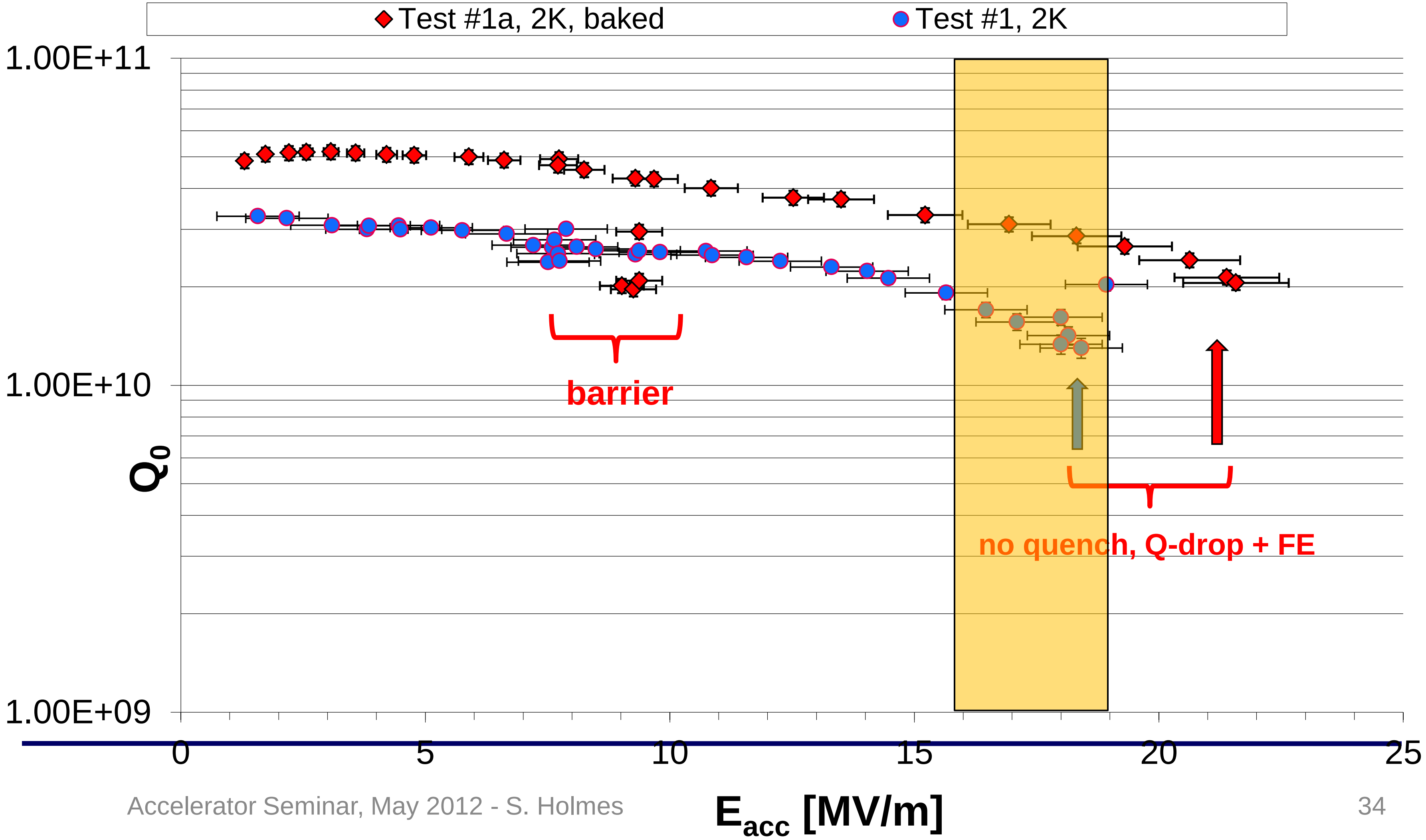
β=0.6/JLab

- Five-cell design complete for β_G = 0.9 cavities
    - Four 5-cell β_G = 0.9 cavities on order from AES; two expected in FY12



650 MHz

Single Cell Performance (JLab, β=0.6)

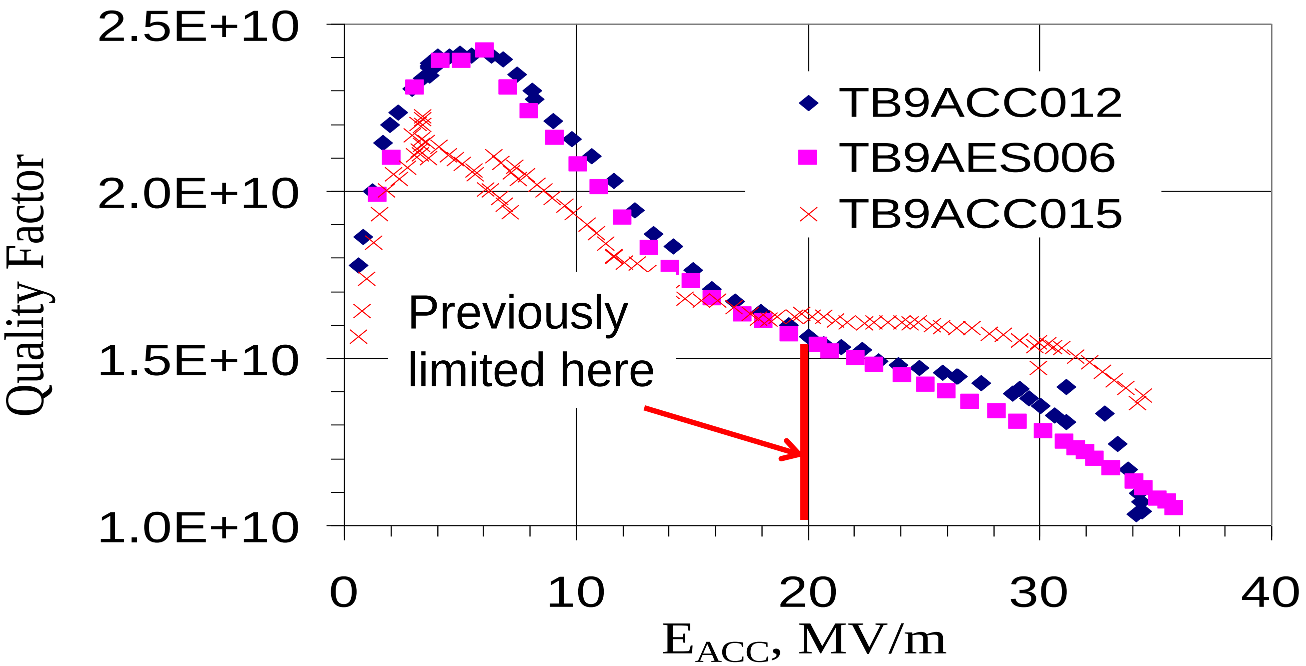


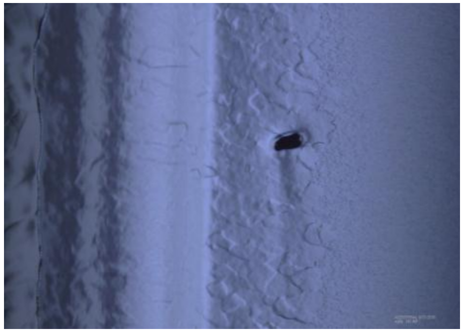
Centrifugal Barrel Polishing
IB4 Tumbling Machine

C. Cooper Recipe Media

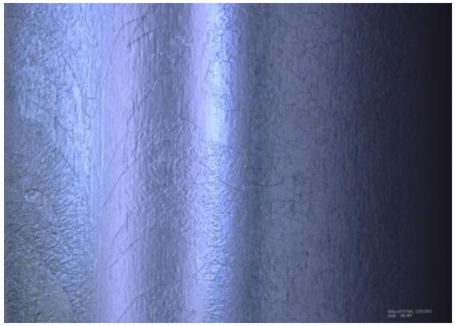
- Multi-step process for elliptical cavities using multiple sets of media
- Potential for up to 4 cavity-cycles per week

Centrifugal Barrel Polishing
9-Cell Results





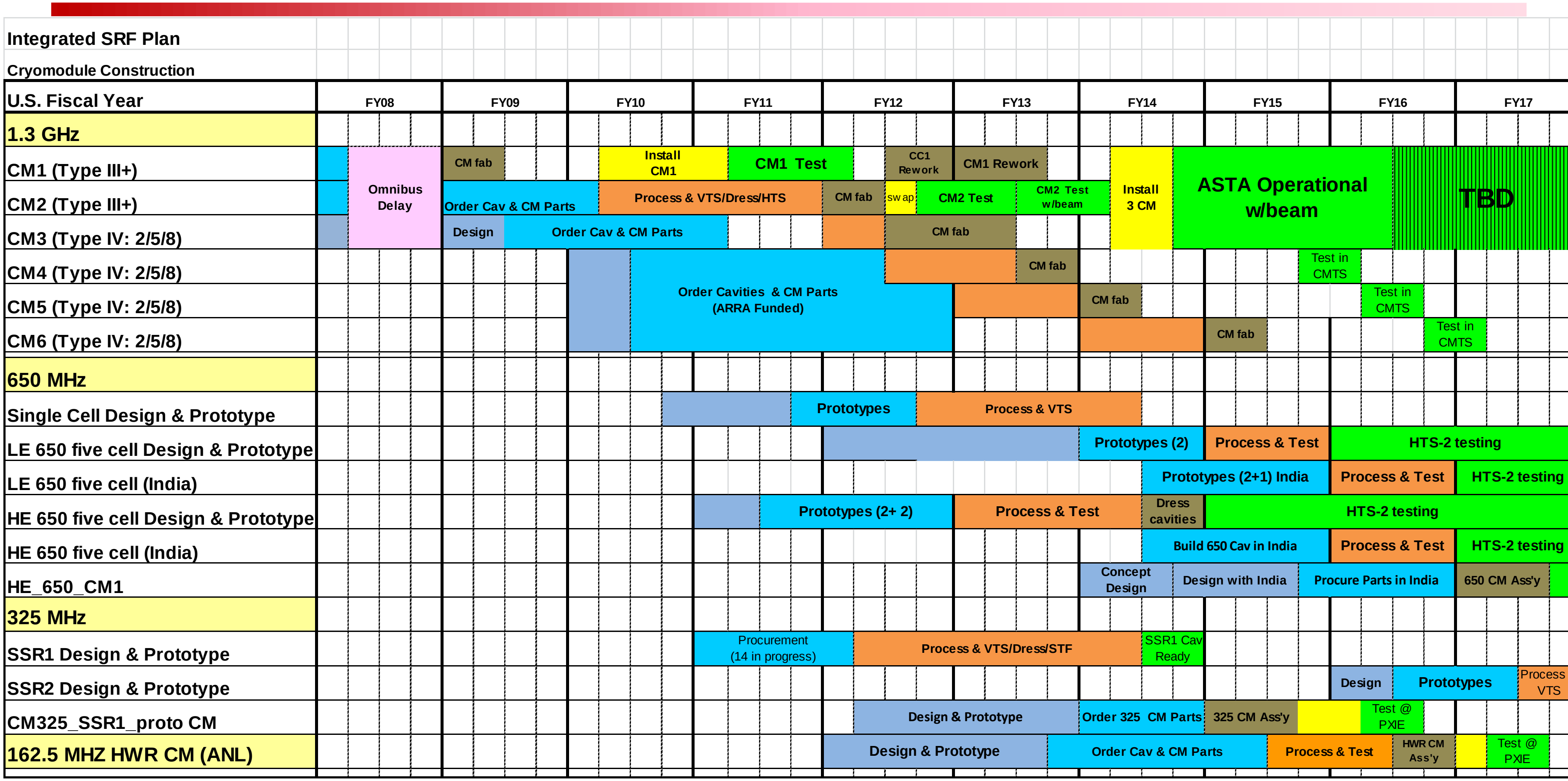
ACC015
Before CBP



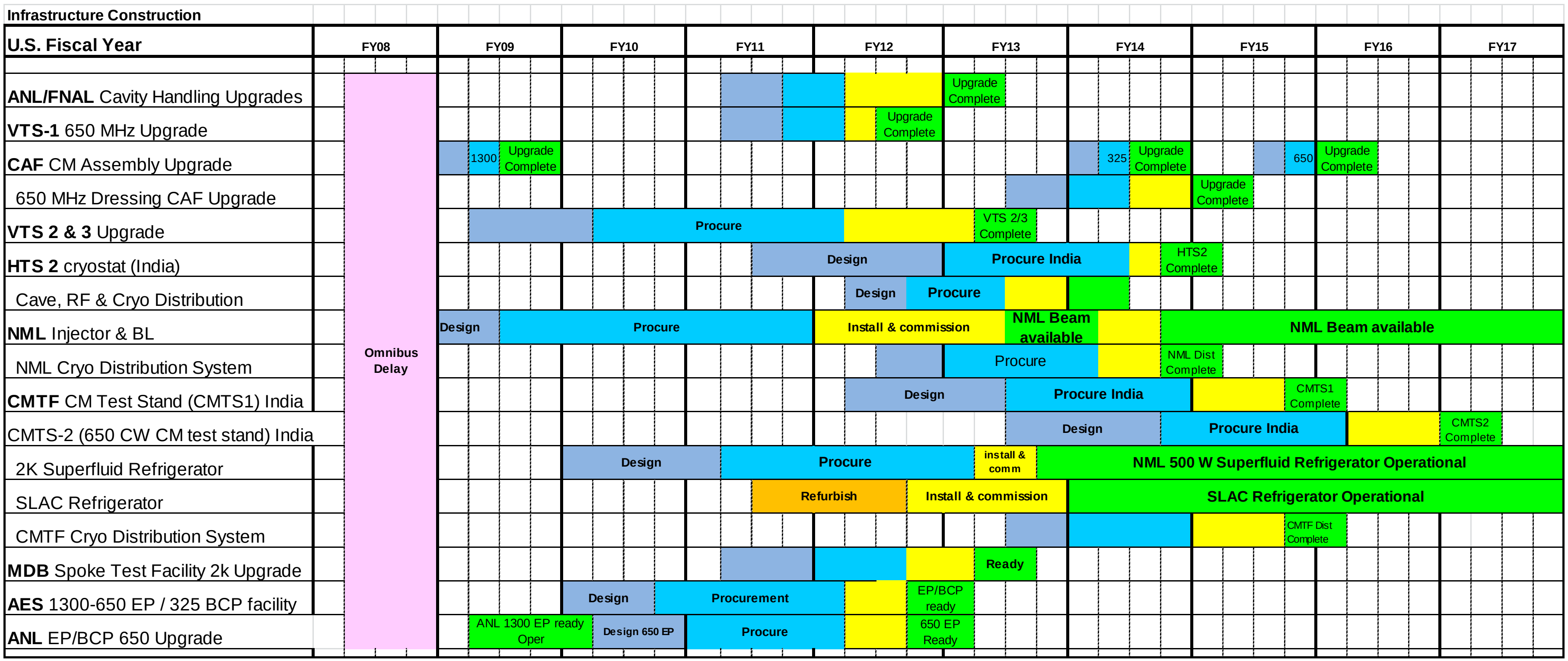
After CBP and 40 μm EP

- Demonstrated cavity gradients > 35 MV/M
- Drastic reductions in acid use.
- Demonstrated as a cavity repair method.

SRF Plan
Cavities & Cryomodules

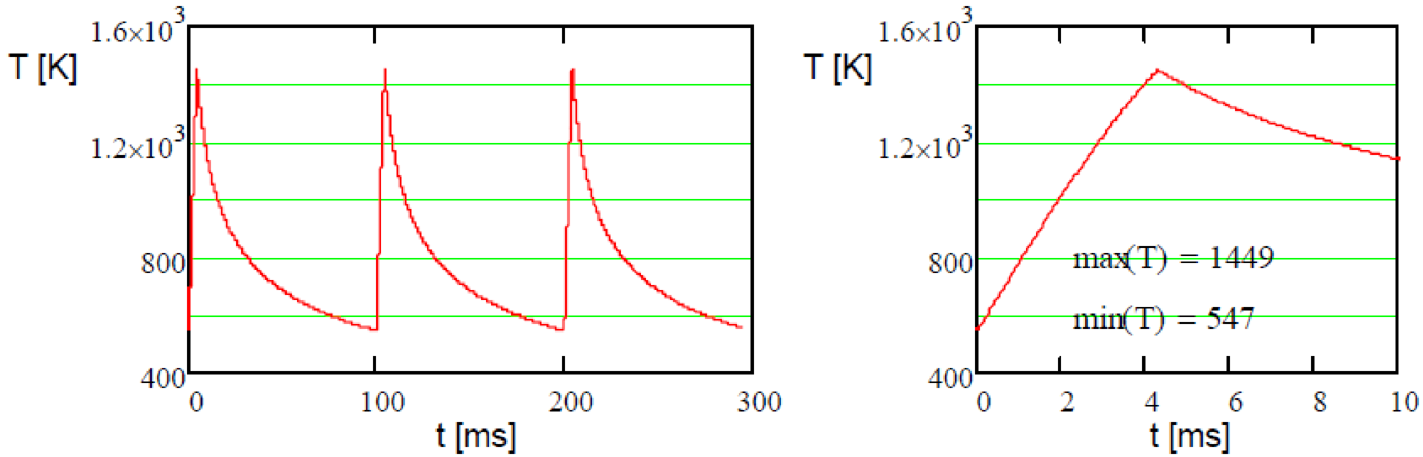


SRF Plan Infrastructure



R&D
H- Injection

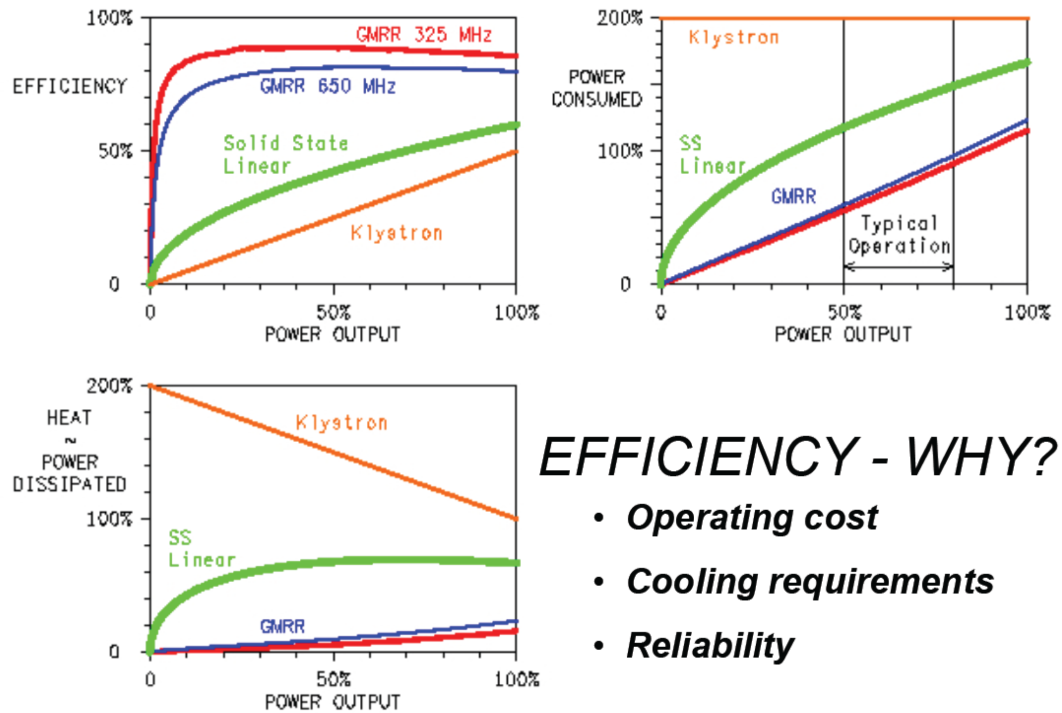
- Need to accumulate 26 mA-ms protons in the MI/Recycler (RD)
  - For a stationary foil, a single 26-ms pulse would destroy the foil.
  - 6 pulses at 10 Hz provide sufficient radiative cooling between pulses
    - ~400 turns
  - Also looking at moving/rotating foils and laser assisted stripping
- 1 mA-msec protons required to load the Booster in Stage 1
  - 600 turns



Dependence of maximum foil temperature on time, only radiative cooling is taken into account

R&D
RF Sources

- 162.5 and 325 MHz sources will be solid state
  - ~5-20 kW/unit
- Evaluating multiple technologies for 650 MHz
  - IOT
  - Solid State
- 1300 MHz (Stage 3) would be based on klystrons



EFFICIENCY - WHY?

- ***Operating cost***
- ***Cooling requirements***
- ***Reliability***

Project X Status and Strategy

- Project X strategy is strongly tied to the overall DOE Intensity Frontier Strategy
  - LBNE: What will or will not be done is in a state of flux at the moment
    - Two Task Forces established at Fermilab
- Project X strategy is strongly tied to the overall fiscal condition of the U.S.
  - Strong message from the DOE on staging
- We remain well supported financially for the R&D phase
  - $13M in FY12 and FY13 + significant investment in srf
- Significant effort is going into defining the physics research opportunities at all stages
  - Recent workshops on opportunities with spallation sources and on short baseline neutrinos
  - Project X Physics Study schedule June 14-23, 2012
  - Snowmass 2013 in planning stages (DPF)
- A significant contribution from India is a strong possibility

Project X Status and Strategy

- Strategy
  - Develop the physics case and mobilize support within the community
    - Includes outreach to non-HEP communities
  - Maintain the RDR as the description of the ultimate goal
  - Maintain the cost estimate for the RDR, with the Stage 1 piece easily segregated
  - Develop a Reference Design description for Stage 1
  - Pursue the PXIE program as a priority within the Project X R&D program
  - Maintain an R&D plan based on a flat-budget
  - Be immediately responsive to DOE when they ask for information

Collaboration Activities

- Two MOUs covering the RD&D Phase

National		IIFC
ANL	ORNL/SNS	BARC/Mumbai
BNL	PNNL	IUAC/Delhi
Cornell	TJNAF	RRCAT/Indore
Fermilab	SLAC	VECC/Kolkata
LBNL	ILC/ART	
MSU		

- Informal collaboration/contacts with CERN/SPL, ESS China/ADS, UK, Korea/KoRIA
- Weekly Friday meeting: https://indico.fnal.gov/categoryDisplay.py?categId=168
  - Collaborator participation via webex
  - Meeting notes posted
- Semi-annual Collaboration meetings

Summary

- The Reference Design represents a unique facility, which would form the basis for a decades long, world leading Intensity Frontier program at Fermilab
  - Project X Reference Design concept has remained stable for two years
- Funding constraints within the DOE have led us to identify staging scenarios
  - Stage 1, based on a 1 GeV CW linac feeding the existing Booster, represents a very significant step in performance of the Fermilab complex, and offers both compelling physics opportunities and a platform for further development toward the Reference Design.
- R&D program underway with very significant investment in srf
  - Emphasis on the CW linac/Stage 1 components, including front end development program (PXIE)
- Significant effort is being invested in defining physics programs associated with all stages

$\Rightarrow$ Go to Bob Tschirhart's colloquium tomorrow to hear more about this!

"Project X and the Endless Frontier", Fermilab Colloquium, Wednesday, May 9

Backup Slides

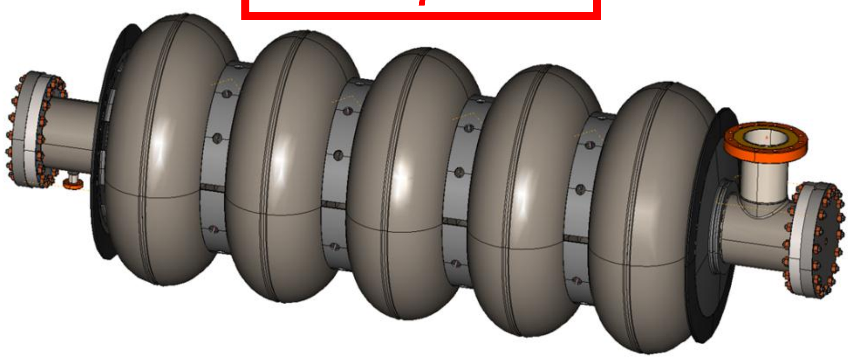
650 MHz Five-Cell Cavity and CW CM Design Status

Project X

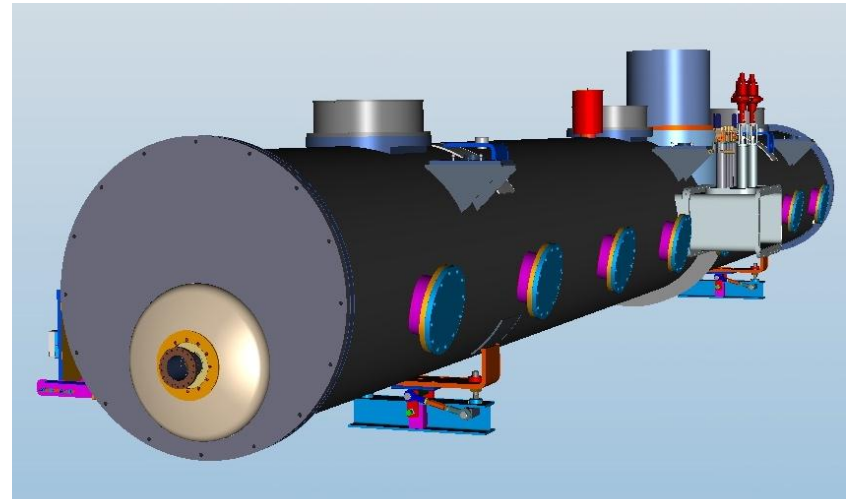
- Cavity drawing package and specification done

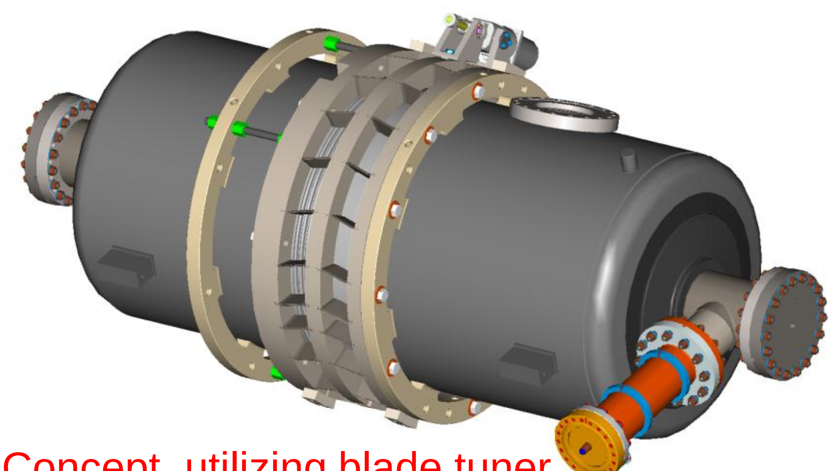
- CW CM conceptual design advanced
  - stand-alone 8-cavity cryomodule
  - Overall length: ~12 m, 48 " O.D.

5-cell β= 0.9

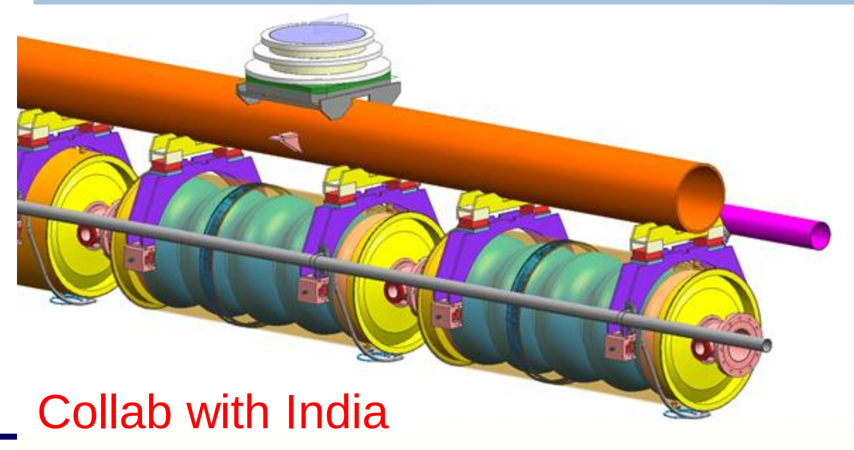


- Stiffening rings located to minimize dF/dP while maintaining tunability





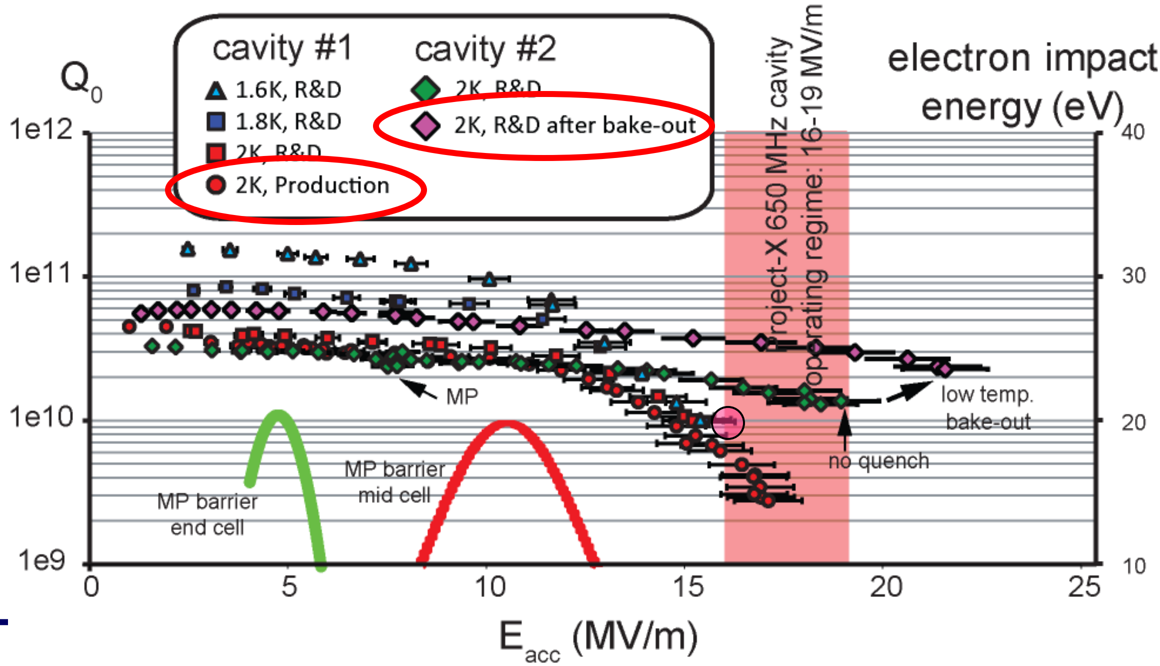
Concept utilizing blade tuner



Collab with India

650 MHz Cavity
(β_G=0.6)

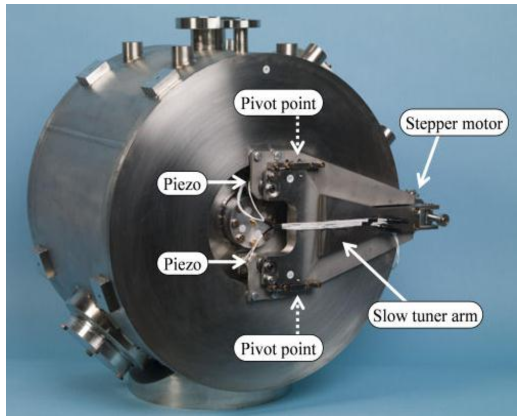
- Standard processing including light BCP (no EP)
- Spec: Q0>8.8E9 at 2K for Eacc=16 MV/m and Q0>1.3E10 at 2K for Eacc=19 MV/m
  - Q0 requirement achieved at 16 MV/m for cavity #2
- Further surface processing likely to bring both cavities up to performance requirement;
- EP may not be required
- Mechanical studies required to extend design to 5-cell

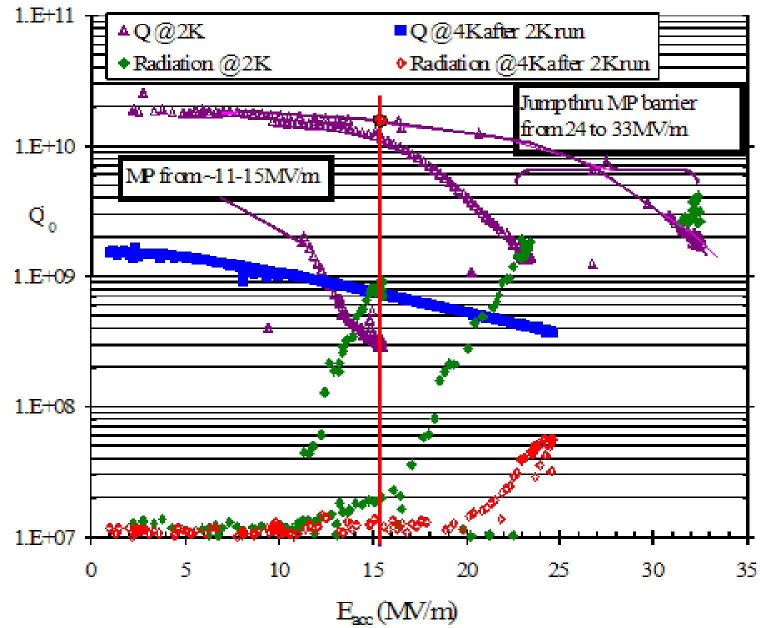


Test Facilities

- New Muon Lab (NML) facility under construction for ILC RF unit test
  - Three CM’s driven from a single rf source
  - 9 mA x 1 msec beam pulse
  - Large extension and supporting infrastructure under construction
    - Refrigerator to support full duty factor operations
    - Cryomodule test stands for all frequencies
    - Building extension for additional CM’s and beam diagnostic area
- The Meson Detector Building (MDB) Test Facility ultimately comprises:
  - 2.5 – 10 MeV beam (p, H-): 1% duty factor, 3 msec pulse
    - 325 MHz superconducting spoke cavity beam tests
    - Chopper tests
    - H^- beam instrumentation development
  - Shielded enclosures and RF power systems for testing individual, dressed 3.9, GHz, 1.3 GHz, 650 MHz, and 325 MHz superconducting RF cavities

SRF Development
325 MHz



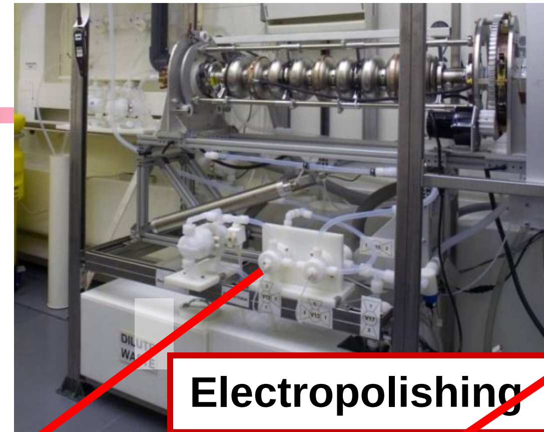


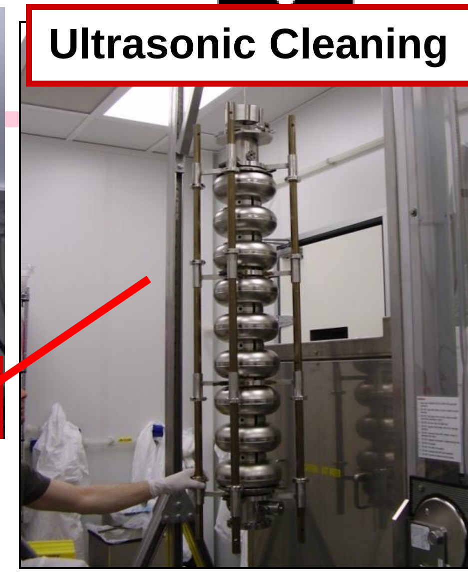
- SSR1 (β=0.22) cavity under development
  - Two prototypes assembled and tested
  - Both meet Project X specification at 2 K
- Preliminary designs for SSR0 and SSR2

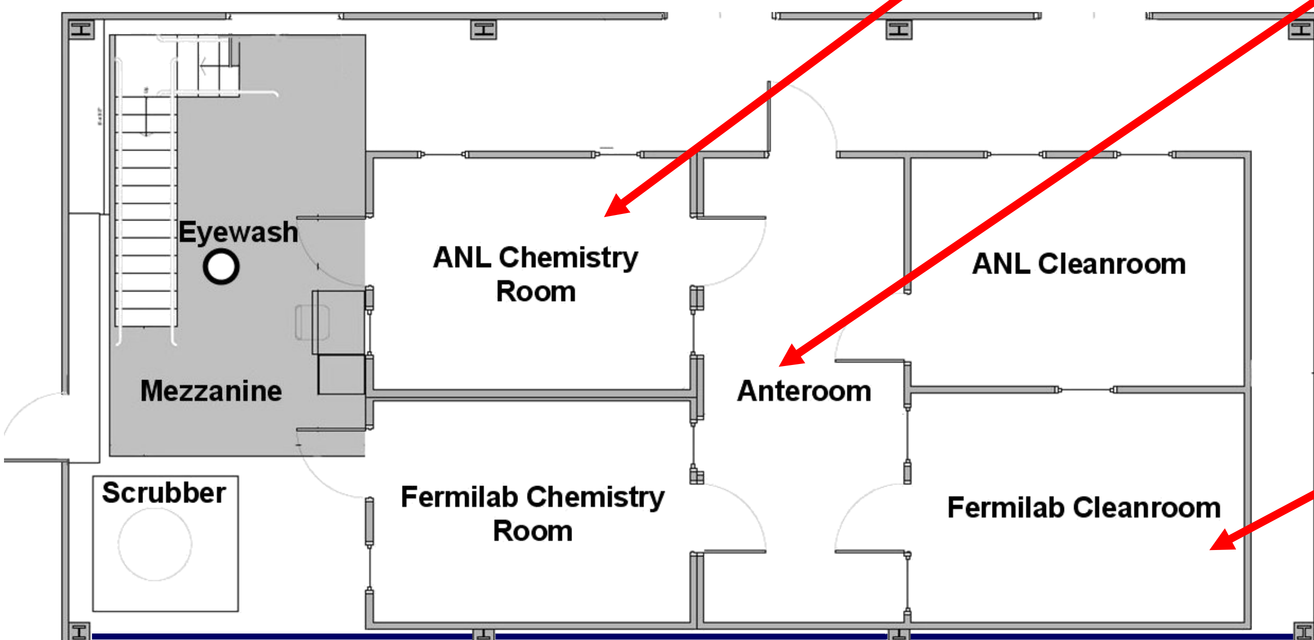
Cavity processing at Argonne

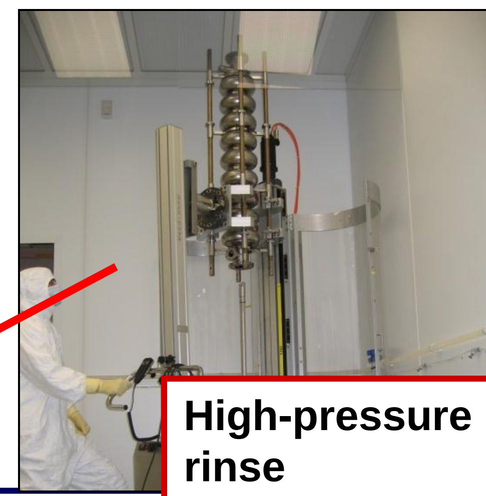
Project X

- Joint facility built by ANL/FNAL collaboration
- EP processing of 9-cells has started
- Together with Jlab, ANL/FNAL facility represents the best cavity processing facilities in the US for ILC or Project X



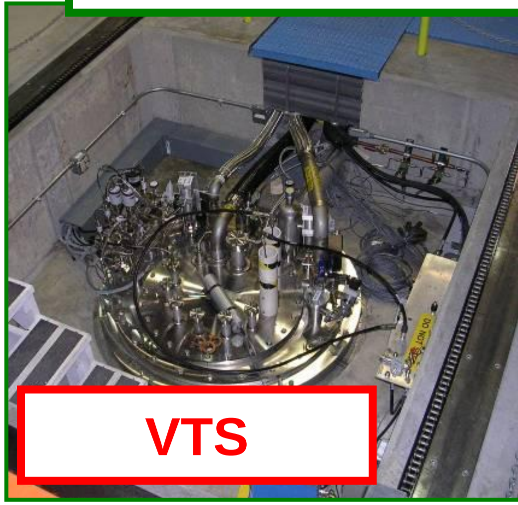




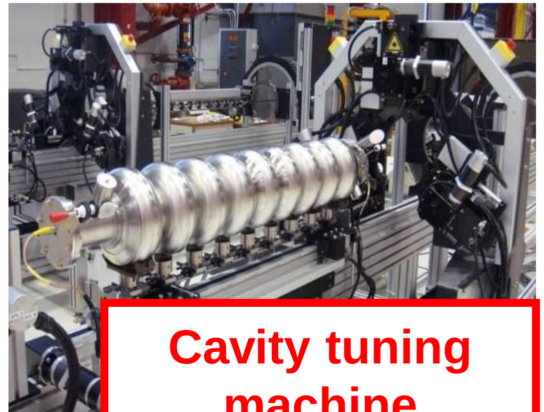


Fermilab SRF infrastructure

VTS



VTS



Cavity tuning machine

HTS

String Assembly

MP9 Clean Room

Final Assembly

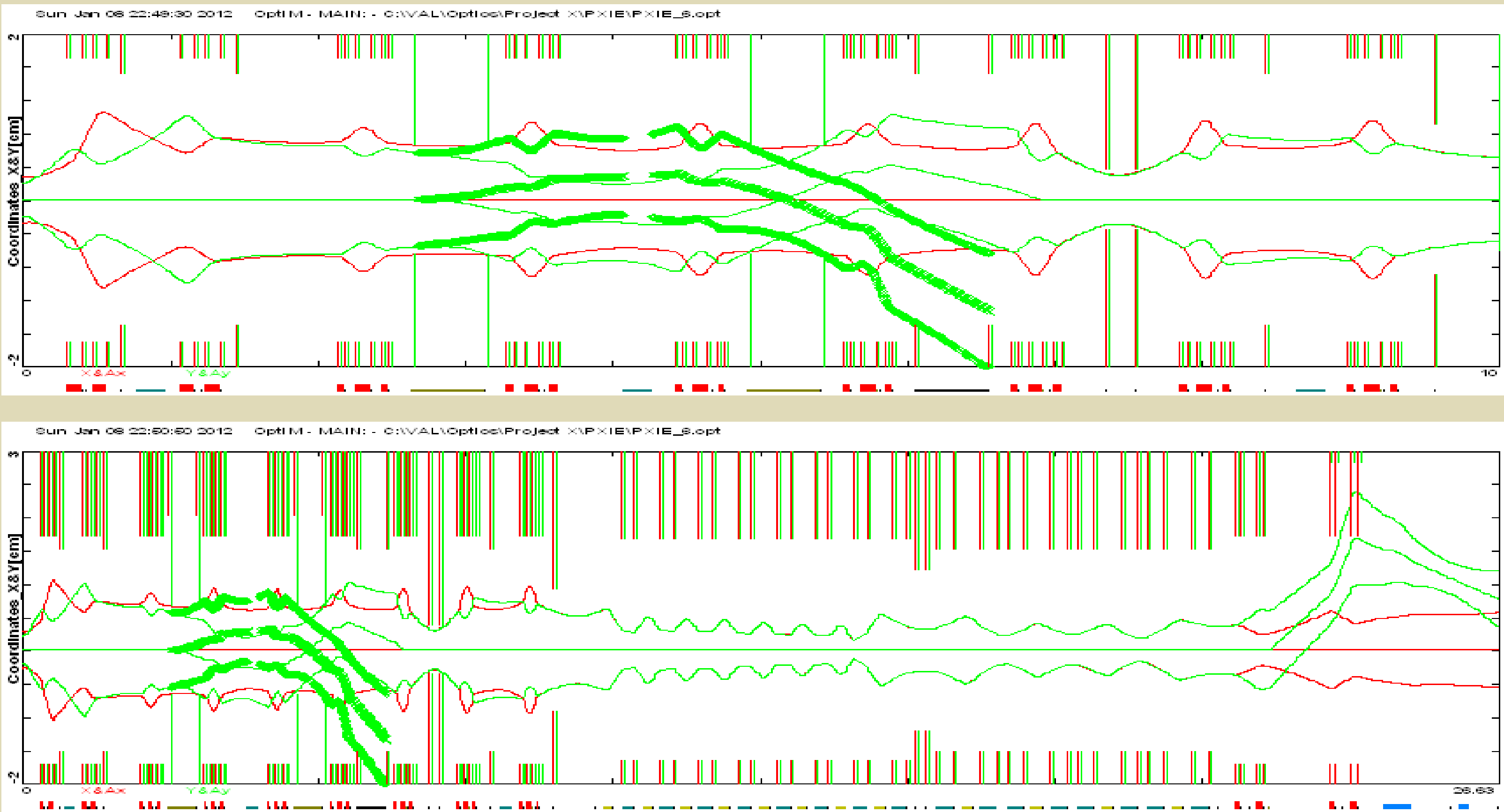
1st U.S. built ILC/PX Cryomodule

1st Dressed Cavity

PXIE
Beam Envelopes w/ Chopping

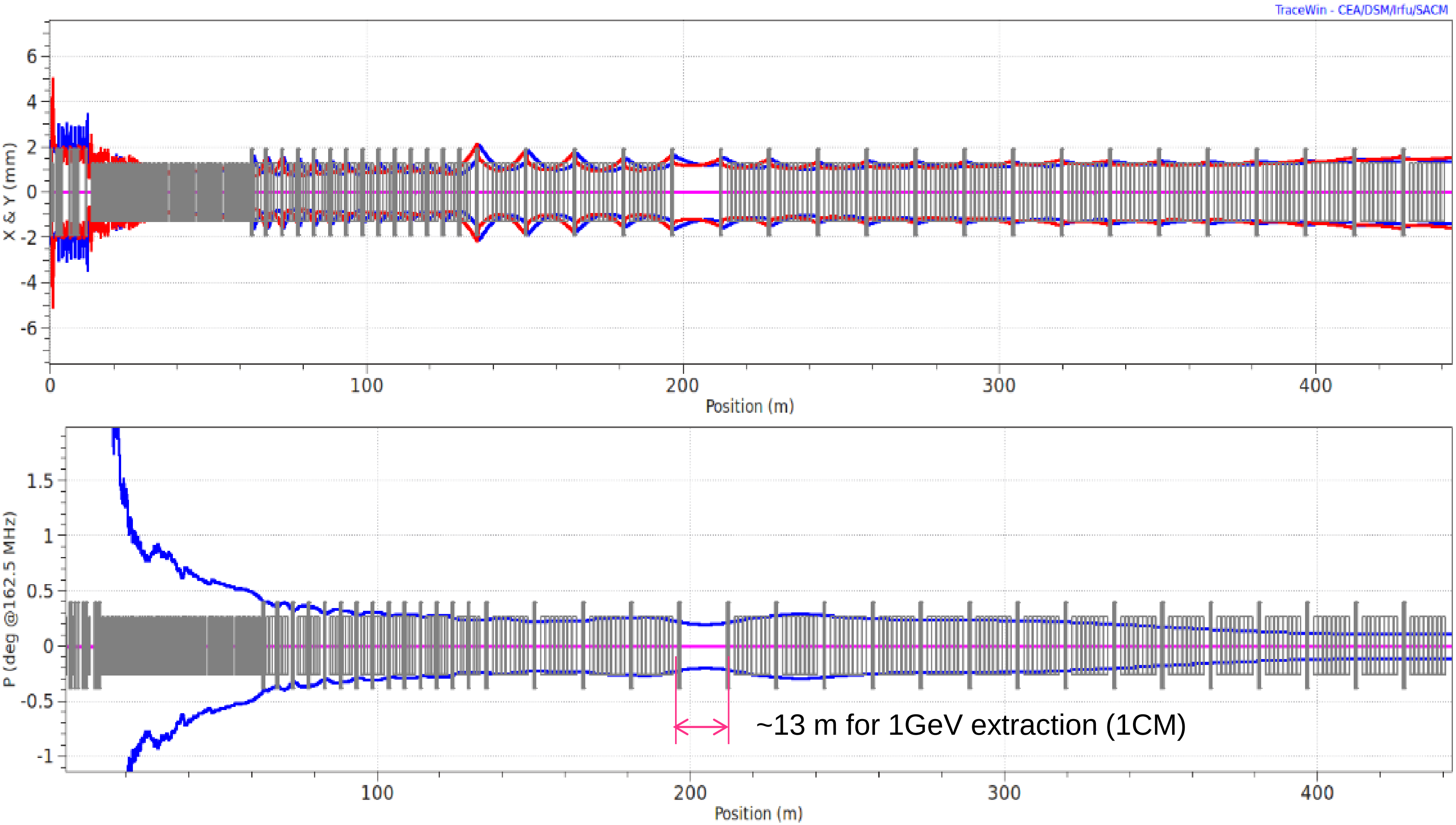
Beam Envelopes

V.Lebedev, *Jan.9, 2012*

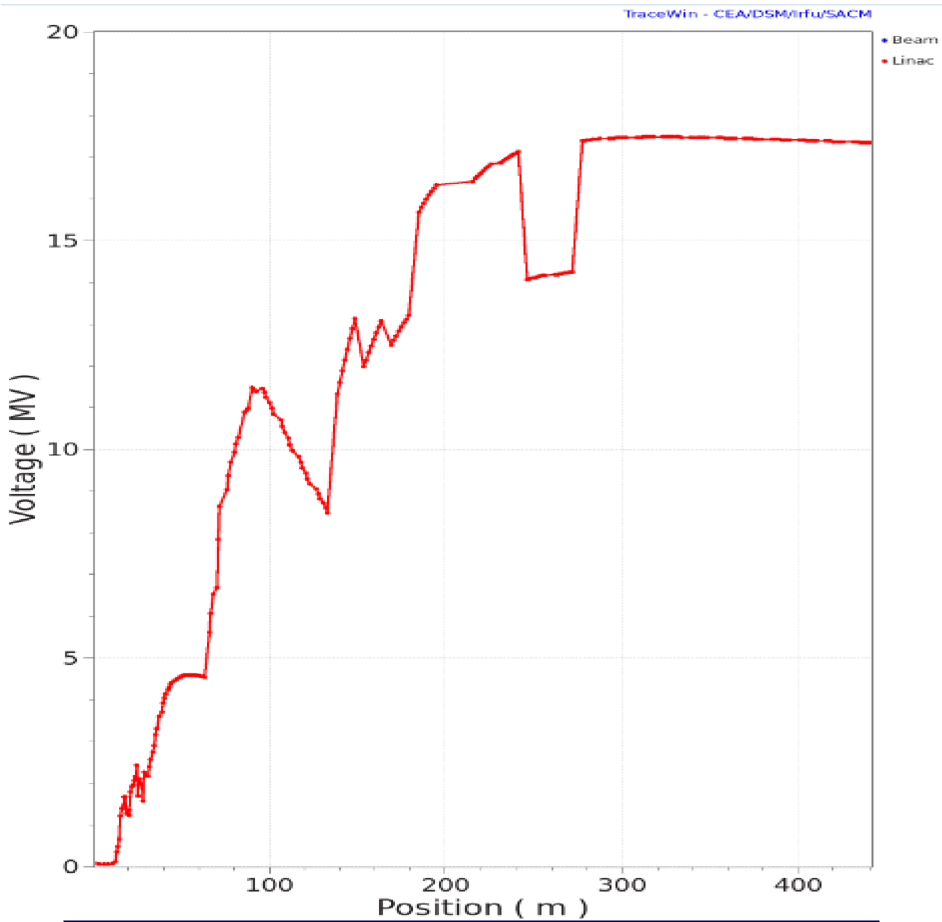


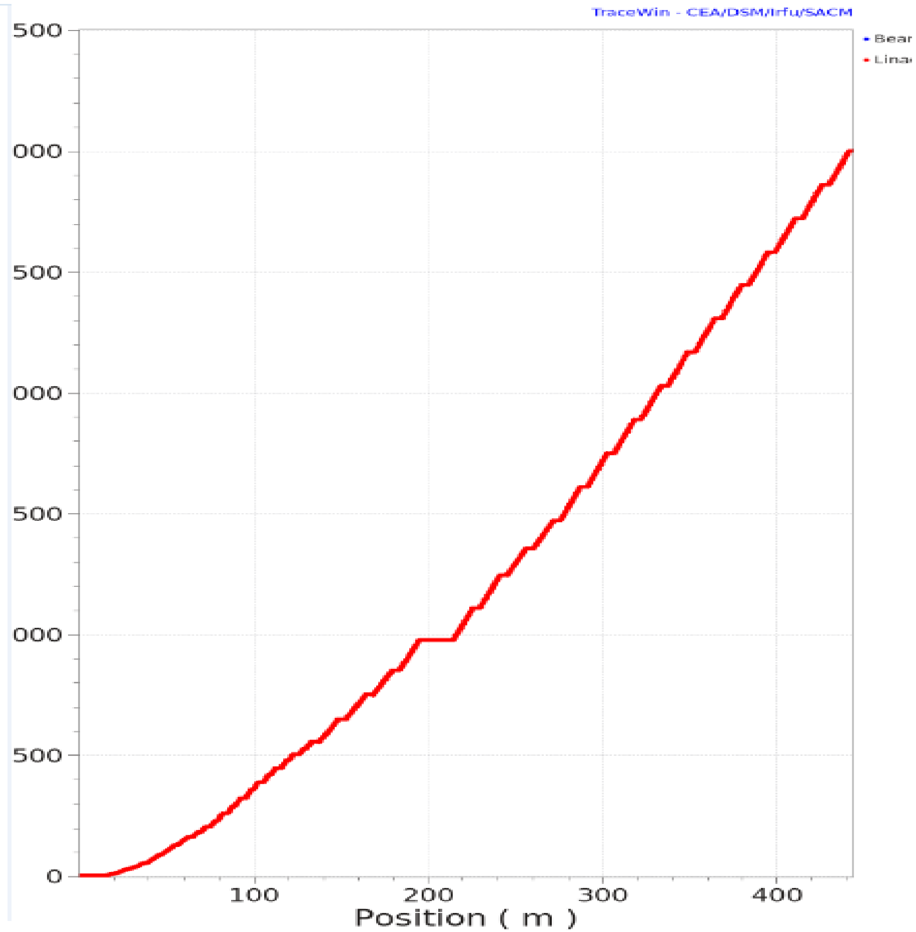
3s beam envelopes through MEBT (top) and from RFQ end to the beam dump (bottom); rms norm. emittance 0.25 mm mrad; thick green lines show the beam envelope for beam extracted to the MEBT beam dump

Total Lattice of CW 3 GeV Linac



Gradient and energy

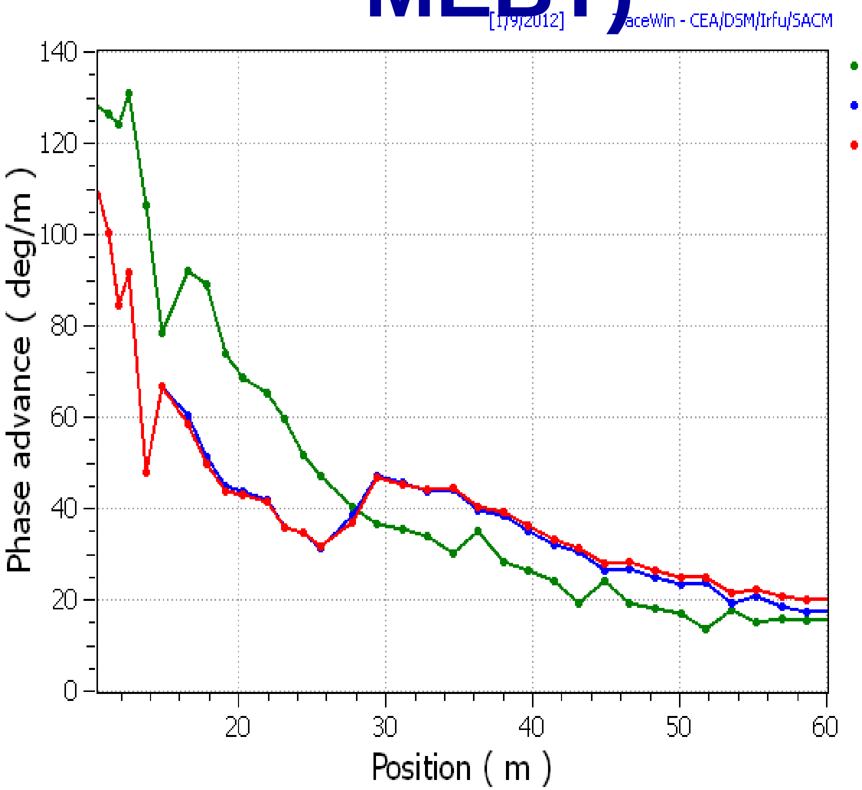


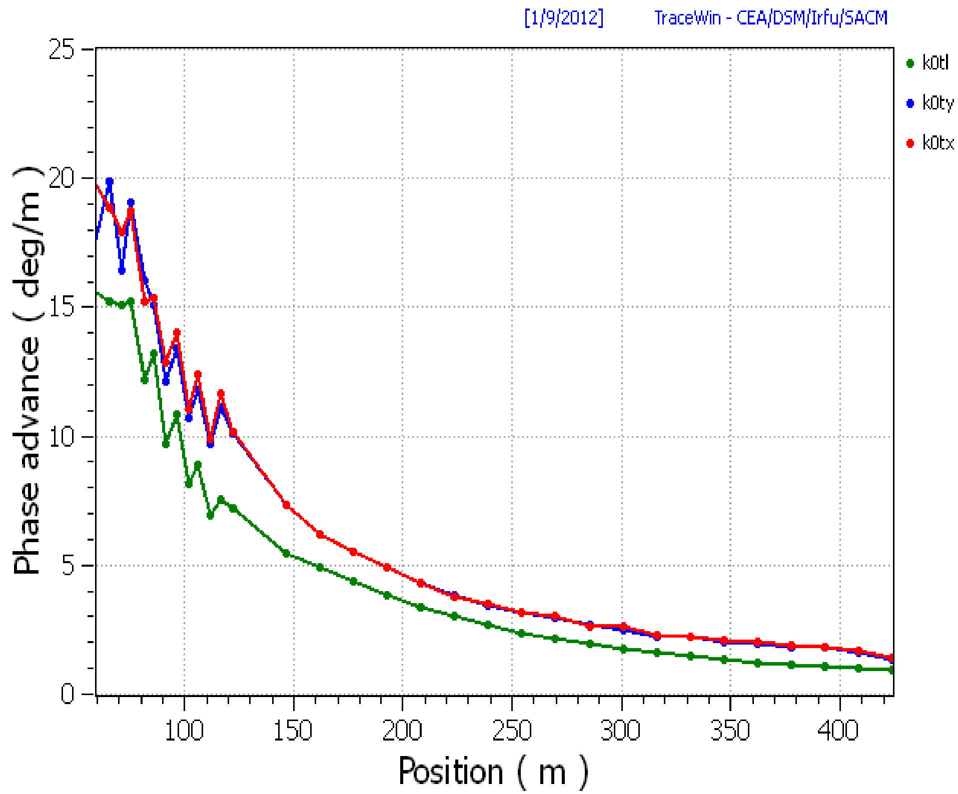


Phase advance

Front End (w/o MEBT)

High energy sections

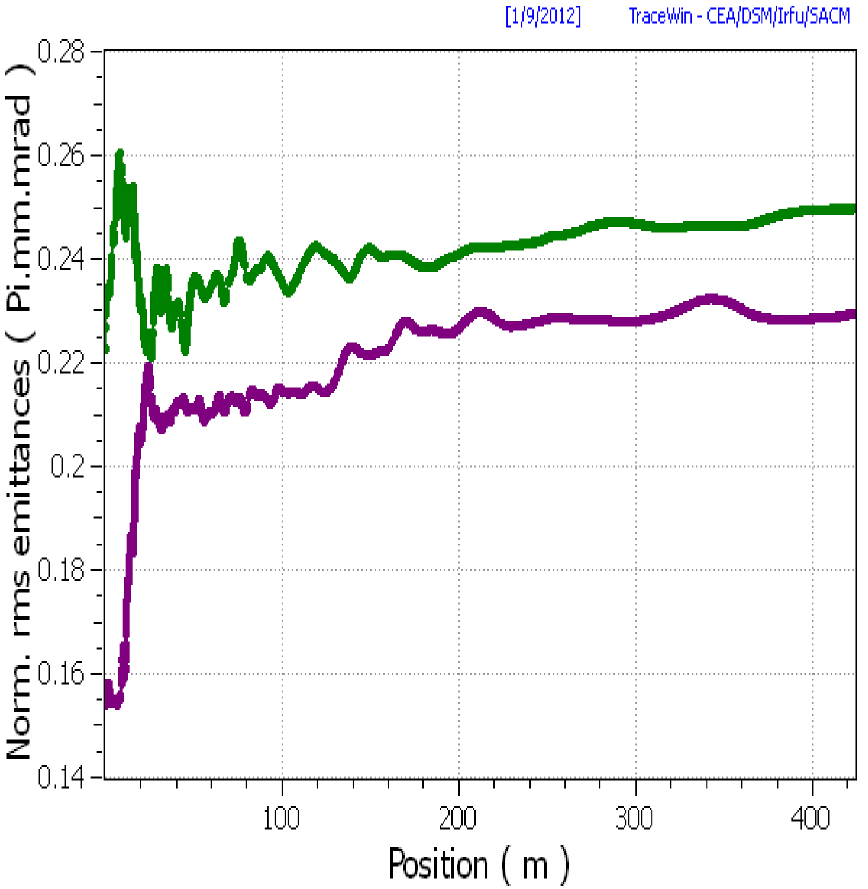


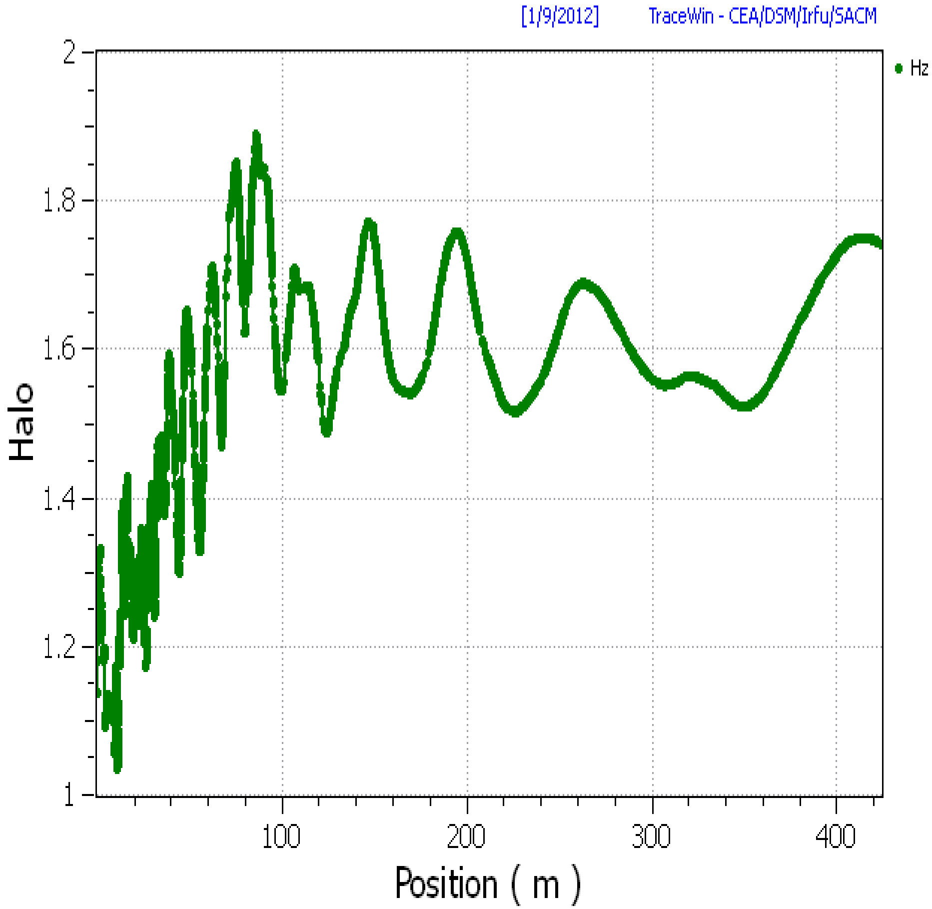


Project X

Emittance

Halo parameter





Initial distribution are taken from latest design of RFQ (Oct.2011, J.Staples)

Project X

Cryogenic losses/cavity

Beam Power